Trigonometry

Trigonometric Functions

T1. $$\sin^2 x + \cos^2 x = 1$$

T2. $$\tan^2 x + 1 = \sec^2 x$$

T3. $$\cot^2 x + 1 = \csc^2 x$$

T4. $$\sin(x \pm y) = \sin x \, \cos y \pm \cos x \, \sin y$$

T5. $$\cos(x \pm y) = \cos x \, \cos y \mp \sin x \, \sin y$$

T6. $$\tan(x \pm y) = \frac{\tan x \pm \tan y}{1 \mp \tan x \, \tan y}$$

T7. $$\sin(2x) = 2 \sin x \, \cos x$$

T8. $$\cos(2x) = \cos^2 x - \sin^2 x$$

T9. $$\sin^2 x = {}^1\!/_2(1 - \cos(2x))$$

T10. $$\cos^2 x = {}^1\!/_2(1 + \cos(2x))$$

T11. $$\sin x \, \sin y = {}^1\!/_2\big(\cos(x - y) - \cos(x + y)\big)$$

T12. $$\cos x \, \cos y = {}^1\!/_2\big(\cos(x - y) + \cos(x + y)\big)$$

T13. $$\sin x \, \cos y = {}^1\!/_2\big(\sin(x - y) + \sin(x + y)\big)$$

T14. $$c_1 \cos(\omega t) + c_2 \sin(\omega t) = \sqrt{c_1^2 + c_2^2}\, \sin(\omega t + \phi),$$

$$\text{where } \phi = 2 \arctan \frac{c_1}{c_2 + \sqrt{c_1^2 + c_2^2}}$$

Hyperbolic Functions

T15. $$\cosh x = \frac{e^x + e^{-x}}{2}$$

T16. $$\sinh x = \frac{e^x - e^{-x}}{2}$$

T17. $$\cosh^2 x - \sinh^2 x = 1$$

T18. $$\tanh^2 x + \operatorname{sech}^2 x = 1$$

T19. $$\coth^2 x - \operatorname{csch}^2 x = 1$$

T20. $$\sinh(x \pm y) = \sinh x \, \cosh y \pm \cosh x \, \sinh y$$

T21. $$\cosh(x \pm y) = \cosh x \, \cosh y \pm \sinh x \, \sinh y$$

T22. $$\tanh(x \pm y) = \frac{\tanh x \pm \tanh y}{1 \pm \tanh x \, \tanh y}$$

T23. $$\sinh(2x) = 2 \sinh x \, \cosh x$$

T24. $$\cosh(2x) = \cosh^2 x + \sinh^2 x$$

T25. $$\sinh x \, \sinh y = {}^1\!/_2\big(\cosh(x+y) - \cosh(x-y)\big)$$

T26. $$\cosh x \, \cosh y = {}^1\!/_2\big(\cosh(x+y) + \cosh(x-y)\big)$$

T27. $$\sinh x \cosh y = \tfrac{1}{2}\big(\sinh(x+y) + \sinh(x-y)\big)$$

Power Series

P1. $$e^x = \sum_{n=0}^{\infty} \frac{x^n}{n!} = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \cdots, \quad -\infty < x < \infty$$

P2. $$\sin x = \sum_{n=0}^{\infty} (-1)^n \frac{x^{2n+1}}{(2n+1)!} = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \cdots, \quad -\infty < x < \infty$$

P3. $$\cos x = \sum_{n=0}^{\infty} (-1)^n \frac{x^{2n}}{(2n)!} = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \cdots, \quad -\infty < x < \infty$$

P4. $$\tan x = x + \frac{x^3}{3} + \frac{2}{15}x^5 + \frac{17}{315}x^7 + \cdots, \quad -\frac{\pi}{2} < x < \frac{\pi}{2}$$

P5. $$\frac{1}{1-x} = \sum_{n=0}^{\infty} x^n = 1 + x + x^2 + x^3 + \cdots, \quad -1 < x < 1$$

P6. $$\sinh x = \sum_{n=0}^{\infty} \frac{x^{2n+1}}{(2n+1)!} = x + \frac{x^3}{3!} + \frac{x^5}{5!} + \cdots, \quad -\infty < x < \infty$$

P7. $$\cosh x = \sum_{n=0}^{\infty} \frac{x^{2n}}{(2n)!} = 1 + \frac{x^2}{2!} + \frac{x^4}{4!} + \cdots, \quad -\infty < x < \infty$$

P8. $$\tanh x = x - \frac{x^3}{3} + \frac{2}{15}x^5 - \frac{17}{315}x^7 + \cdots, \quad -\frac{\pi}{2} < x < \frac{\pi}{2}$$

P9. $$f(x) = f(a) + f'(a)(x-a) + \frac{f''(a)}{2!}(x-a)^2 + \frac{f'''(a)}{3!}(x-a)^3 + \cdots$$

P10. Taylor Series with remainder:

$$f(x) = \sum_{n=0}^{N} \frac{f^{(n)}(a)}{n!}(x-a)^n + R_{N+1}(x), \quad \text{where}$$

$$R_{N+1}(x) = \frac{f^{(N+1)}(\xi)}{(N+1)!}(x-a)^{N+1} \qquad \text{for some } \xi \text{ between } a \text{ and } x$$

Table of Integrals

A constant of integration should be added to each formula. The letters a, b, m, and n denote constants; u and v denote functions of an independent variable such as x.

Standard Integrals

I1. $$\int u^n \, du = \frac{u^{n+1}}{n+1}, \quad n \neq -1$$

I2. $$\int \frac{du}{u} = \ln |u|$$

I3. $$\int e^u \, du = e^u$$

I4. $$\int a^u \, du = \frac{a^u}{\ln a}, \quad a > 0$$

I5. $$\int \cos u \, du = \sin u$$

I6. $$\int \sin u \, du = -\cos u$$

I7. $$\int \sec^2 u \, du = \tan u$$

I8. $$\int \csc^2 u \, du = -\cot u$$

I9. $$\int \sec u \tan u \, du = \sec u$$

I10. $$\int \csc u \cot u \, du = -\csc u$$

I11. $$\int \tan u \, du = -\ln |\cos u|$$

I12. $$\int \cot u \, du = \ln|\sin u|$$

I13. $$\int \sec u \, du = \ln|\sec u + \tan u|$$

I14. $$\int \csc u \, du = \ln|\csc u - \cot u|$$

I15. $$\int \frac{du}{a^2 + u^2} = \frac{1}{a} \arctan\left(\frac{u}{a}\right)$$

I16. $$\int \frac{du}{\sqrt{a^2 - u^2}} = \arcsin\left(\frac{u}{a}\right)$$

I17. $$\int u \, dv = uv - \int v \, du$$

Integrals involving $au + b$

I18. $$\int (au+b)^n du = \frac{(au+b)^{n+1}}{(n+1)a}, \quad n \neq -1$$

I19. $$\int \frac{du}{au+b} = \frac{1}{a} \ln|au+b|$$

I20. $$\int \frac{u \, du}{au+b} = \frac{u}{a} - \frac{b}{a^2} \ln|au+b|$$

I21. $$\int \frac{u \, du}{(au+b)^2} = \frac{b}{a^2(au+b)} + \frac{1}{a^2} \ln|au+b|$$

I22. $$\int \frac{du}{u(au+b)} = \frac{1}{b} \ln\left|\frac{u}{au+b}\right|$$

I23. $$\int u\sqrt{au+b} \, du = \frac{2(3au-2b)}{15a^2}(au+b)^{3/2}$$

I24. $$\int \frac{u \, du}{\sqrt{au+b}} = \frac{2(au-2b)}{3a^2}\sqrt{au+b}$$

I25. $$\int u^2\sqrt{au+b} \, du = \frac{2}{105a^3}\left(8b^2 - 12abu + 15a^2u^2\right)(au+b)^{3/2}$$

I26. $$\int \frac{u^2\,du}{\sqrt{au+b}} = \frac{2}{15a^3}\left(8b^2 - 4abu + 3a^2u^2\right)\sqrt{au+b}$$

Integrals involving $u^2 \pm a^2$

I27. $$\int \frac{du}{u^2-a^2} = \frac{1}{2a}\ln\left|\frac{u-a}{u+a}\right|$$

I28. $$\int \frac{u\,du}{u^2 \pm a^2} = {}^1\!/\!_2 \ln\left|u^2 \pm a^2\right|$$

I29. $$\int \frac{u^2\,du}{u^2-a^2} = u + \frac{a}{2}\ln\left|\frac{u-a}{u+a}\right|$$

I30. $$\int \frac{u^2\,du}{u^2+a^2} = u - a\arctan\left(\frac{u}{a}\right)$$

I31. $$\int \frac{du}{u(u^2 \pm a^2)} = \pm\frac{1}{2a^2}\ln\left|\frac{u^2}{u^2 \pm a^2}\right|$$

Integrals involving $\sqrt{u^2 \pm a^2}$

I32. $$\int \frac{u\,du}{\sqrt{u^2 \pm a^2}} = \sqrt{u^2 \pm a^2}$$

I33. $$\int u\sqrt{u^2 \pm a^2}\,du = \frac{1}{3}\left(u^2 \pm a^2\right)^{3/2}$$

I34. $$\int \frac{du}{\sqrt{u^2 \pm a^2}} = \ln\left|u + \sqrt{u^2 \pm a^2}\right|$$

I35. $$\int \frac{u^2\,du}{\sqrt{u^2 \pm a^2}} = \frac{u}{2}\sqrt{u^2 \pm a^2} \mp \frac{a^2}{2}\ln\left|u + \sqrt{u^2 \pm a^2}\right|$$

I36. $$\int \frac{du}{u\sqrt{u^2+a^2}} = \frac{1}{a}\ln\left|\frac{u}{a+\sqrt{u^2+a^2}}\right|$$

I37. $$\int \frac{du}{u\sqrt{u^2-a^2}} = \frac{1}{a}\operatorname{arcsec}\left(\frac{u}{a}\right)$$

I38. $$\int \frac{du}{u^2\sqrt{u^2 \pm a^2}} = \mp \frac{\sqrt{u^2 \pm a^2}}{a^2 u}$$

I39. $$\int \sqrt{u^2 \pm a^2}\, du = \frac{u}{2}\sqrt{u^2 \pm a^2} \pm \frac{a^2}{2} \ln\left| u + \sqrt{u^2 \pm a^2} \right|$$

I40. $$\int u^2 \sqrt{u^2 \pm a^2}\, du = \frac{u}{4}\left(u^2 \pm a^2\right)^{3/2} \mp \frac{a^2 u}{8}\sqrt{u^2 \pm a^2} - \frac{a^4}{8} \ln\left| u + \sqrt{u^2 \pm a^2} \right|$$

I41. $$\int \frac{\sqrt{u^2 + a^2}}{u}\, du = \sqrt{u^2 + a^2} - a \ln\left| \frac{a + \sqrt{u^2 + a^2}}{u} \right|$$

I42. $$\int \frac{\sqrt{u^2 - a^2}}{u}\, du = \sqrt{u^2 - a^2} - a \operatorname{arcsec}\left(\frac{u}{a}\right)$$

I43. $$\int \frac{\sqrt{u^2 \pm a^2}}{u^2}\, du = -\frac{\sqrt{u^2 \pm a^2}}{u} + \ln\left| u + \sqrt{u^2 \pm a^2} \right|$$

Integrals involving $\sqrt{a^2 - u^2}$

I44. $$\int \sqrt{a^2 - u^2}\, du = \frac{u}{2}\sqrt{a^2 - u^2} + \frac{a^2}{2} \arcsin\left(\frac{u}{a}\right)$$

I45. $$\int \frac{u\, du}{\sqrt{a^2 - u^2}} = -\sqrt{a^2 - u^2}$$

I46. $$\int u\sqrt{a^2 - u^2}\, du = -\frac{1}{3}\left(a^2 - u^2\right)^{3/2}$$

I47. $$\int \frac{\sqrt{a^2 - u^2}}{u}\, du = \sqrt{a^2 - u^2} - a \ln\left| \frac{a + \sqrt{a^2 - u^2}}{u} \right|$$

I48. $$\int \frac{du}{u\sqrt{a^2 - u^2}} = -\frac{1}{a} \ln\left| \frac{a + \sqrt{a^2 - u^2}}{u} \right|$$

I49. $$\int u^2 \sqrt{a^2 - u^2}\, du = -\frac{u}{4}\left(a^2 - u^2\right)^{3/2} + \frac{a^2 u}{8}\sqrt{a^2 - u^2} + \frac{a^4}{8} \arcsin\left(\frac{u}{a}\right)$$

I50. $$\int \frac{\sqrt{a^2 - u^2}}{u^2}\, du = -\frac{\sqrt{a^2 - u^2}}{u} - \arcsin\left(\frac{u}{a}\right)$$

I51. $$\int \frac{u^2\,du}{\sqrt{a^2-u^2}} = -\frac{u}{2}\sqrt{a^2-u^2} + \frac{a^2}{2}\arcsin\left(\frac{u}{a}\right)$$

I52. $$\int \frac{du}{u^2\sqrt{a^2-u^2}} = -\frac{\sqrt{a^2-u^2}}{a^2u}$$

Integrals involving trigonometric functions

I53. $$\int \sin^2(au)\,du = \frac{u}{2} - \frac{\sin(2au)}{4a}$$

I54. $$\int \cos^2(au)\,du = \frac{u}{2} + \frac{\sin(2au)}{4a}$$

I55. $$\int \sin^3(au)\,du = \frac{1}{a}\left(\frac{\cos^3(au)}{3} - \cos(au)\right)$$

I56. $$\int \cos^3(au)\,du = \frac{1}{a}\left(\sin(au) - \frac{\sin^3(au)}{3}\right)$$

I57. $$\int \sin^2(au)\,\cos^2(au)\,du = \frac{u}{8} - \frac{1}{32a}\sin(4au)$$

I58. $$\int \tan^2(au)\,du = \frac{1}{a}\tan(au) - u$$

I59. $$\int \cot^2(au)\,du = -\frac{1}{a}\cot(au) - u$$

I60. $$\int \sec^3(au)\,du = \frac{1}{2a}\sec(au)\tan(au) + \frac{1}{2a}\ln|\,\sec(au)+\tan(au)\,|$$

I61. $$\int \csc^3(au)\,du = -\frac{1}{2a}\csc(au)\cot(au) + \frac{1}{2a}\ln|\,\csc(au)-\cot(au)\,|$$

I62. $$\int u\sin(au)\,du = \frac{1}{a^2}\left(\sin(au) - au\cos(au)\right)$$

I63. $$\int u\cos(au)\,du = \frac{1}{a^2}\left(\cos(au) + au\sin(au)\right)$$

I64. $$\int u^2\sin(au)\,du = \frac{1}{a^3}\left(2au\sin(au) - (\,a^2u^2 - 2\,)\cos(au)\right)$$

I65. $$\int u^2 \cos(au)\, du = \frac{1}{a^3}\left(2au\cos(au) + (\,a^2u^2 - 2\,)\sin(au)\right)$$

I66. $$\int \sin(au)\ \sin(bu)\, du = \frac{\sin(a-b)u}{2(a-b)} - \frac{\sin(a+b)u}{2(a+b)}, \qquad a^2 \neq b^2$$

I67. $$\int \cos(au)\ \cos(bu)\, du = \frac{\sin(a-b)u}{2(a-b)} + \frac{\sin(a+b)u}{2(a+b)}, \qquad a^2 \neq b^2$$

I68. $$\int \sin(au)\ \cos(bu)\, du = -\frac{\cos(a-b)u}{2(a-b)} - \frac{\cos(a+b)u}{2(a+b)}, \qquad a^2 \neq b^2$$

I69. $$\int \sin^n u\, du = -\frac{1}{n}\sin^{n-1} u \cos u + \frac{n-1}{n}\int \sin^{n-2} u\, du$$

Integrals involving hyperbolic functions

I70. $$\int \sinh(au)\, du = \frac{1}{a}\cosh(au)$$

I71. $$\int \sinh^2(au)\, du = \frac{1}{4a}\sinh(2au) - \frac{u}{2}$$

I72. $$\int \cosh(au)\, du = \frac{1}{a}\sinh(au)$$

I73. $$\int \cosh^2(au)\, du = \frac{u}{2} + \frac{1}{4a}\sinh(2au)$$

I74. $$\int \sinh(au)\ \cosh(bu)\, du = \frac{\cosh\left((a+b)\,u\right)}{2(a+b)} + \frac{\cosh\left((a-b)\,u\right)}{2(a-b)}$$

I75. $$\int \sinh(au)\ \cosh(au)\, du = \frac{1}{4a}\cosh(2au)$$

I76. $$\int \tanh u\, du = \ln(\cosh u)$$

I77. $$\int \operatorname{sech} u\, du = \arctan(\sinh u) = 2\arctan\left(e^u\right)$$

Integrals involving exponential functions

I78. $$\int ue^{au}\,du = \frac{e^{au}}{a^2}(au-1)$$

I79. $$\int u^2e^{au}\,du = \frac{e^{au}}{a^3}\left(a^2u^2-2au+2\right)$$

I80. $$\int u^ne^{au}\,du = \frac{1}{a}u^ne^{au} - \frac{n}{a}\int u^{n-1}e^{au}\,du$$

I81. $$\int e^{au}\sin(bu)\,du = \frac{e^{au}}{a^2+b^2}\left(a\sin(bu)-b\cos(bu)\right)$$

I82. $$\int e^{au}\cos(bu)\,du = \frac{e^{au}}{a^2+b^2}\left(a\cos(bu)+b\sin(bu)\right)$$

Integrals involving inverse trigonometric functions

I83. $$\int \arcsin\left(\frac{u}{a}\right)\,du = u\arcsin\left(\frac{u}{a}\right)+\sqrt{a^2-u^2}$$

I84. $$\int \arccos\left(\frac{u}{a}\right)\,du = u\arccos\left(\frac{u}{a}\right)-\sqrt{a^2-u^2}$$

I85. $$\int \arctan\left(\frac{u}{a}\right)\,du = u\arctan\left(\frac{u}{a}\right)-\frac{a}{2}\ln\left(a^2+u^2\right)$$

Integrals involving inverse hyperbolic functions

I86. $$\int \operatorname{arcsinh}\left(\frac{u}{a}\right)\,du = u\operatorname{arcsinh}\left(\frac{u}{a}\right)-\sqrt{u^2+a^2}$$

I87. $$\begin{aligned}\int \operatorname{arccosh}\left(\frac{u}{a}\right)\,du &= u\operatorname{arccosh}\left(\frac{u}{a}\right)-\sqrt{u^2-a^2} \qquad \operatorname{arccosh}\left(\frac{u}{a}\right)>0;\\ &= u\operatorname{arccosh}\left(\frac{u}{a}\right)+\sqrt{u^2-a^2} \qquad \operatorname{arccosh}\left(\frac{u}{a}\right)<0.\end{aligned}$$

I88. $$\int \operatorname{arctanh}\left(\frac{u}{a}\right)\,du = u\operatorname{arctanh}\left(\frac{u}{a}\right)+\frac{a}{2}\ln\left(a^2-u^2\right)$$

Integrals involving logarithm functions

I89. $$\int \ln u \, du = u(\ln u - 1)$$

I90. $$\int u^n \ln u \, du = u^{n+1}\left[\frac{\ln u}{n+1} - \frac{1}{(n+1)^2}\right], \qquad n \neq -1$$

Wallis' Formulas

I91. $$\begin{aligned}\int_0^{\pi/2} \sin^m x \, dx &= \int_0^{\pi/2} \cos^m x \, dx \\ &= \frac{(m-1)(m-3)\ldots(2 \text{ or } 1)}{m(m-2)\ldots(3 \text{ or } 2)} k,\end{aligned}$$

where $k = 1$ if m is odd and $k = \pi/2$ if m is even.

I92. $$\int_0^{\pi/2} \sin^m x \, \cos^n x \, dx = \frac{(m-1)(m-3)\ldots(2 \text{ or } 1)(n-1)(n-3)\ldots(2 \text{ or } 1)}{(m+n)(m+n-2)\ldots(2 \text{ or } 1)} k,$$

where $k = \pi/2$ if both m and n are even and $k = 1$ otherwise.

Gamma Function

$$\Gamma(x) = \int_0^\infty t^{x-1} e^{-t} \, dt, \qquad x > 0$$

$$\Gamma(x+1) = x\Gamma(x)$$

$$\Gamma\left(1/2\right) = \sqrt{\pi}$$

$$\Gamma(n+1) = n!, \qquad \text{if } n \text{ is a non-negative integer}$$

Fourier Series

$$f(x) = \frac{a_0}{2} + \sum_{n=1}^{\infty}\Big(a_n \cos\frac{n\pi x}{L} + b_n \sin\frac{n\pi x}{L}\Big)$$

where

$$a_0 = \frac{1}{L}\int_{-L}^{L} f(x)\,dx,$$

$$a_n = \frac{1}{L}\int_{-L}^{L} f(x)\cos\frac{n\pi x}{L}\,dx,$$

$$b_n = \frac{1}{L}\int_{-L}^{L} f(x)\sin\frac{n\pi x}{L}\,dx.$$

$$f(x) = \sum_{n=-\infty}^{\infty} c_n e^{ni\pi x/L}$$

where

$$c_n = \frac{1}{2L}\int_{-L}^{L} f(x)e^{-ni\pi x/L}\,dx.$$

Bessel Functions

ν = arbitrary real number; n = integer

1. Definition.
   $x^2y'' + xy' + (\lambda^2x^2 - \nu^2)y = 0$ has solutions

$$y = y_\nu(\lambda x) = c_1 J_\nu(\lambda x) + c_2 J_{-\nu}(\lambda x), \qquad (\nu \neq n),$$

where

$$J_\nu(t) = \sum_{m=0}^{\infty} \frac{(-1)^m\, t^{\nu+2m}}{2^{\nu+2m}\, m!\,\Gamma(\nu+m+1)}.$$

2. General Properties.

$$J_{-n}(t) = (-1)^n J_n(t); \quad J_0(0) = 1; \quad J_n(0) = 0, \qquad (n \geq 1).$$

3. Identities.

(a) $\dfrac{d}{dt}[t^\nu J_\nu(t)] = t^\nu J_{\nu-1}(t).$

(b) $\dfrac{d}{dt}[t^{-\nu} J_\nu(t)] = -t^{-\nu} J_{\nu+1}(t); \qquad \dfrac{d}{dt} J_0(t) = -J_1(t).$

(c)

$$\begin{aligned}\frac{d}{dt} J_\nu(t) &= {}^1\!/_2\,(J_{\nu-1}(t) - J_{\nu+1}(t)) \\ &= J_{\nu-1}(t) - \frac{\nu}{t} J_\nu(t) \\ &= \frac{\nu}{t} J_\nu(t) - J_{\nu+1}(t)\,.\end{aligned}$$

(d) Recurrence Relation.

$$J_{\nu+1}(t) = \frac{2\nu}{t} J_\nu(t) - J_{\nu-1}(t)$$

4. Orthogonality.

Solutions $y_\nu(\lambda_0 x),\ y_\nu(\lambda_1 x),\ \ldots, y_\nu(\lambda_n x), \ldots$ of the differential system

$$x^2 y'' + xy' + (\lambda^2 x^2 - \nu^2) y = 0, \qquad x_1 \le x \le x_2$$

$$a_k y_\nu(\lambda x_k) - b_k \left(\frac{d}{dx} y_\nu(\lambda x)\right)\Bigg|_{x=x_k} = 0, \qquad k = 1, 2$$

have the orthogonality property:

$$\int_{x_1}^{x_2} x y_\nu(\lambda_n x) y_\nu(\lambda_m x)\, dx = 0, \qquad (m \ne n)$$

and

$$\int_{x_1}^{x_2} x y_\nu^2(\lambda_m x)\, dx =$$

$$\frac{1}{2\lambda_m^2}\left[\left(\lambda_m^2 x^2 - \nu^2\right) y_\nu^2(\lambda_m x) + x^2 \left(\frac{d}{dx} y_\nu\left(\lambda_m x\right)\right)^2\right]_{x_1}^{x^2}, \qquad (m = n)\,.$$

5. Integrals.

(a) $\displaystyle\int t^\nu J_{\nu-1}(t)\, dt = t^\nu J_\nu(t) + C$

(b) $\displaystyle\int t^{-\nu} J_{\nu+1}(t)\,dt = -t^{-\nu} J_\nu(t) + C$

(c) $\displaystyle\int t\,J_0(t)\,dt = tJ_1(t) + C$

(d) $\displaystyle\int t^3 J_0(t)\,dt = (t^3 - 4t)J_1(t) + 2t^2 J_0(t) + C$

(e) $\displaystyle\int t^2 J_1(t)\,dt = 2tJ_1(t) - t^2 J_0(t) + C$

(f) $\displaystyle\int t^4 J_1(t)\,dt = (4t^3 - 16t)J_1(t) - (t^4 - 8t^2)J_0(t) + C$

Zeros and Associated Values of Bessel Functions				
α	$j_{0,\alpha}$	$J_0'(j_{0,\alpha})$	$j_{1,\alpha}$	$J_1'(j_{1,\alpha})$
1	2.40483	-0.519147	3.83170	-0.402760
2	5.52008	0.340265	7.01559	0.300116
3	8.65373	-0.271452	10.1735	-0.249705
4	11.7915	0.232460	13.3237	0.218359
5	14.9309	-0.206546	16.4706	-0.196465
6	18.0711	0.187729	19.6159	0.180063
7	21.2116	-0.173266	22.7601	-0.167185
8	24.3525	0.161702	25.9037	0.156725
9	27.4935	-0.152181	29.0468	-0.148011
10	30.6346	0.144166	32.1897	0.140606
11	33.7758	-0.137297	35.3323	-0.134211
12	36.9171	0.131325	38.4748	0.128617
13	40.0584	-0.126069	41.6171	-0.123668
14	43.1998	0.121399	44.7593	0.119250
15	46.3412	-0.117211	47.9015	-0.115274
16	49.4826	0.113429	51.0435	0.111670
17	52.6241	-0.109991	54.1856	-0.108385
18	55.7655	0.106848	57.3275	0.105374
19	58.9070	-0.103960	60.4695	-0.102601
20	62.0485	0.101293	63.6114	0.100035

Legendre Polynomials

1. $(1 - x^2)y'' - 2xy' + n(n+1)y = 0$ has bounded solutions

$$P_n(x), \qquad n = 0, 1, 2, \ldots,$$

on $-1 \le x \le 1$ where

$$P_n(x) = \sum_{k=0}^{N} \frac{(-1)^k\,(2n-2k)!}{2^n\,k!\,(n-k)!\,(n-2k)!}\,x^{n-2k}$$

where

$$N = \frac{n}{2}, \quad \text{n even} \qquad \text{or} \qquad N = \frac{n-1}{2}, \quad \text{n odd}$$

2.

$$\begin{aligned} P_0(x) &= 1 \\ P_1(x) &= x \\ P_2(x) &= {}^1\!/_2(3x^2-1) \\ P_3(x) &= {}^1\!/_2(5x^3-3x) \\ P_4(x) &= \frac{1}{8}(35x^4-30x^2+3) \\ P_5(x) &= \frac{1}{8}(63x^5-70x^3+15x) \end{aligned}$$

3. $P_n(1) = 1.$

4. $P_n(-x) = (-1)^n P_n(x).$

5. $P_n(x) = \dfrac{1}{2^n n!}\dfrac{d^n}{dx^n}(x^2-1)^n$ **Rodrigues' Formula**

6. $P_{n+1}(x) = \dfrac{2n+1}{n+1}xP_n(x) - \dfrac{n}{n+1}P_{n-1}(x), \qquad n \ge 1.$

7. $nP_n(x) = xP_n'(x) - P_{n-1}'(x), \qquad n \ge 1.$

8. $\displaystyle\int_x^1 P_n(t)\,dt = \frac{1}{2n+1}\left(P_{n-1}(x) - P_{n+1}(x)\right), \qquad n \ge 1.$

9. $\displaystyle\int_{-1}^1 P_n(x)P_m(x)\,dx = 0, \qquad m \ne n.$

10. $\displaystyle\int_{-1}^1 P_n^2(x)\,dx = \frac{2}{2n+1}.$

11. $\displaystyle\int_{-1}^1 x^m P_n(x)\,dx = 0, \qquad m < n.$

Table of Laplace Transforms

	$f(t) \equiv \mathcal{L}^{-1}\{F(s)\}(t)$	$F(s) \equiv \mathcal{L}\{f(t)\}(s)$
L1.	$f(t)$	$F(s) = \int_0^\infty e^{-st} f(t)\, dt$
L2.	$1,\ H(t),\ U(t)$	$\frac{1}{s}$
L3.	$U(t-a)$	$\frac{e^{-as}}{s}$
L4.	$t^n \quad (n = 1, 2, 3, \ldots)$	$\frac{n!}{s^{n+1}}$
L5.	$t^a \quad (a > -1)$	$\frac{\Gamma(a+1)}{s^{a+1}}$
L6.	e^{at}	$\frac{1}{s-a}$
L7.	$\sin(\omega t)$	$\frac{\omega}{s^2+\omega^2}$
L8.	$\cos(\omega t)$	$\frac{s}{s^2+\omega^2}$
L9.	$f'(t)$	$sF(s) - f(0)$
L10.	$f''(t)$	$s^2F(s) - sf(0) - f'(0)$
L11.	$t^n f(t) \quad (n = 1, 2, 3, \ldots)$	$(-1)^n F^{(n)}(s)$
L12.	$e^{at} f(t)$	$F(s-a)$
L13.	$e^{at}\mathcal{L}^{-1}\{F(s+a)\}$	$F(s)$
L14.	$f(t+P) = f(t)$	$\frac{\int_0^P e^{-st} f(t)\, dt}{1 - e^{-sP}}$

Table of Laplace Transforms

	$f(t) \equiv \mathcal{L}^{-1}\{F(s)\}(t)$	$F(s) \equiv \mathcal{L}\{f(t)\}(s)$
L15.	$f(t)U(t-a)$	$e^{-as}\mathcal{L}\{f(t+a)\}$
L16.	$f(t-a)U(t-a)$	$e^{-as}F(s)$
L17.	$\int_0^t f(z)\,dz$	$\frac{F(s)}{s}$
L18.	$\int_0^t f(z)g(t-z)\,dz$	$F(s)G(s)$
L19.	$\frac{f(t)}{t}$	$\int_s^\infty F(z)\,dz$
L20.	$\frac{1}{a}\left(e^{at}-1\right)$	$\frac{1}{s(s-a)}$
L21.	$t^n e^{at},\ n=1,2,3,\ldots$	$\frac{n!}{(s-a)^{n+1}}$
L22.	$\frac{e^{at}-e^{bt}}{a-b}$	$\frac{1}{(s-a)(s-b)}$
L23.	$\frac{ae^{at}-be^{bt}}{a-b}$	$\frac{s}{(s-a)(s-b)}$
L24.	$\sinh(\omega t)$	$\frac{\omega}{s^2-\omega^2}$
L25.	$\cosh(\omega t)$	$\frac{s}{s^2-\omega^2}$
L26.	$\sin(\omega t)-\omega t\cos(\omega t)$	$\frac{2\omega^3}{(s^2+\omega^2)^2}$
L27.	$t\sin(\omega t)$	$\frac{2\omega s}{(s^2+\omega^2)^2}$
L28.	$\sin(\omega t)+\omega t\cos(\omega t)$	$\frac{2\omega s^2}{(s^2+\omega^2)^2}$

Table of Laplace Transforms

	$f(t) \equiv \mathcal{L}^{-1}\{F(s)\}(t)$	$F(s) \equiv \mathcal{L}\{f(t)\}(s)$
L29.	$\dfrac{b\sin(at) - a\sin(bt)}{ab(b^2 - a^2)}$	$\dfrac{1}{(s^2 + a^2)(s^2 + b^2)}$
L30.	$\dfrac{\cos(at) - \cos(bt)}{b^2 - a^2}$	$\dfrac{s}{(s^2 + a^2)(s^2 + b^2)}$
L31.	$\dfrac{a\sin(at) - b\sin(bt)}{a^2 - b^2}$	$\dfrac{s^2}{(s^2 + a^2)(s^2 + b^2)}$
L32.	$e^{-bt}\sin(\omega t)$	$\dfrac{\omega}{(s+b)^2 + \omega^2}$
L33.	$e^{-bt}\cos(\omega t)$	$\dfrac{s+b}{(s+b)^2 + \omega^2}$
L34.	$1 - \cos(\omega t)$	$\dfrac{\omega^2}{s(s^2 + \omega^2)}$
L35.	$\omega t - \sin(\omega t)$	$\dfrac{\omega^3}{s^2(s^2 + \omega^2)}$
L36.	$\delta(t - a)$	$e^{-sa} \qquad a > 0, \;\; s > 0$
L37.	$\delta(t - a)f(t)$	$f(a)e^{-sa} \qquad a > 0, \;\; s > 0$