Appendices

Operators

In this table:

- **A** and **B** represent arrays, either vector or matrix.
- **u** and **v** represent vectors with real or complex elements.
- **M** represents a square matrix.
- *z* and *w* represent real or complex numbers.
- *x* and *y* represent real numbers.
- *m* and *n* represent integers.
- *i* represents a range variable.
- *S* and any names beginning with *S* represent string expressions.
- *t* represents any variable name.
- *f* represents a function.
- *X* and *Y* represent variables or expressions of any type.

For information about programming operators in Mathcad Professional, see Chapter 15, "Programming." For information about symbolic operators and keywords, see Chapter 14, "Symbolic Calculation."

Operation	Appearance	Keystroke	Description
Parentheses	(X)	'	Grouping operator.
Vector Subscript	$\mathbf{v}_n$	[	Returns indicated element of a vector.
Matrix Subscript	$\mathbf{A}_{m,n}$	[	Returns indicated element of a matrix.
Superscript	$\mathbf{A}^{\langle n \rangle}$	[Ctrl]6	Extracts column *n* from array **A**. Returns a vector.
Vectorize	$\vec{X}$	[Ctrl]–	Forces operations in expression *X* to take place element by element. All vectors or matrices in *X* must be the same size.
Factorial	$n!$	!	Returns $n \cdot (n-1) \cdot (n-2) \ldots$ The integer *n* cannot be negative.
Complex conjugate	$\overline{X}$	"	Inverts the sign of the imaginary part of *X*. This keystroke creates a string expression in a blank placeholder.
Transpose	$\mathbf{A}^{\mathbf{T}}$	[Ctrl]1	Returns a matrix whose rows are the columns of **A** and whose columns are the rows of **A**. **A** can be a vector or a matrix.

Power	z^w	**^**	Raises *z* to the power *w*.
Powers of matrix, matrix inverse	$\mathbf{M}^n$	**^**	*n*th power of square matrix **M** (using matrix multiplication). *n* must be a whole number. $\mathbf{M}^{-1}$ is the inverse of **M**. Other negative powers are powers of the inverse. Returns a square matrix.
Negation	$-X$	**–**	Multiplies *X* by –1.
Vector sum	$\Sigma\mathbf{v}$	**[Ctrl]4**	Sums elements of vector v; returns a scalar.
Square root	$\sqrt{z}$	****	Returns positive square root for positive *z*; principal value for negative or complex *z*.
nth root	$\sqrt[n]{z}$	**[Ctrl]**	Returns *n*th root of *z*; returns a real valued root whenever possible.
Magnitude, Absolute value	$\lvert z \rvert$	**|**	Returns $\sqrt{\mathrm{Re}(z)^2 + \mathrm{Im}(z)^2}$.
Magnitude of vector	$\lvert \mathbf{v} \rvert$	**|**	Returns the magnitude of the vector **v**: $\sqrt{\mathbf{v} \cdot \mathbf{v}}$ if all elements in **v** are real. Returns $\sqrt{\mathbf{v} \cdot \bar{\mathbf{v}}}$ if any element in **v** is complex.
Determinant	$\lvert \mathbf{M} \rvert$	**|**	Returns the determinant of the square matrix **M**. Result is a scalar.
Division	$\frac{X}{z}$	**/**	Divides the expression *X* by the non-zero scalar *z*. If *X* is an array, divides each element by *z*.
Multiplication	$X \cdot Y$	*****	Returns the product of *X* and *Y* if both *X* and *Y* are scalars. Multiplies each element of *Y* by *X* if *Y* is an array and *X* is a scalar. Returns the dot product (inner product) if *X* and *Y* are vectors of the same size. Performs matrix multiplication if *X* and *Y* are conformable matrices.
Cross product	$\mathbf{u} \times \mathbf{v}$	**[Ctrl]8**	Returns cross-product (vector product) for the three-element vectors **u** and **v**.
Summation	$\sum_{i=m}^{n} X$	**[Ctrl] [Shift]4**	Performs summation of *X* over $i = m, m+1, \ldots, n$. *X* can be any expression. It need not involve *i* but it usually does. *m* and *n* must be integers.
Product	$\prod_{i=m}^{n} X$	**[Ctrl] [Shift]3**	Performs iterated product of *X* for $i = m, m+1, \ldots, n$. *X* can be any expression. It need not involve *i* but it usually does. *m* and *n* must be integers.
Range sum	$\sum_{i} X$	**$**	Returns a summation of *X* over the range variable *i*. *X* can be any expression.
Range product	$\prod_{i} X$	**#**	Returns the iterated product of *X* over the range variable *i*. *X* can be any expression.

Integral	$\int_a^b f(t)dt$	**&**	Returns the definite integral of $f(t)$ over the interval $[a, b]$. a and b must be real scalars. All variables in the expression $f(t)$, except the variable of integration t, must be defined. The integrand, $f(t)$, cannot return an array.
Derivative	$\frac{d}{dt}f(t)$	**?**	Returns the derivative of $f(t)$ evaluated at t. All variables in the expression $f(t)$ must be defined. The variable t must be a scalar value. The function $f(t)$ must return a scalar.
nth Derivative	$\frac{d^n}{dt^n}f(t)$	**[Ctrl]?**	Returns the nth derivative of $f(t)$ evaluated at t. All variables in $f(t)$ must be defined. The variable t must be a scalar value. The function $f(t)$ must return a scalar. n must be an integer between 0 and 5 for numerical evaluation or a positive integer for symbolic evaluation.
Addition	$X + Y$	**+**	Scalar addition if X, Y, or both are scalars. Element by element addition if X and Y are vectors or matrices of the same size. If X is an array and Y is a scalar, adds Y to each element of X.
Subtraction	$X - Y$	**–**	Performs scalar subtraction if X, Y, or both are scalars. Performs element by element subtraction if X and Y are vectors or matrices of the same size. If X is an array and Y is a scalar, subtracts Y from each element of X.
Addition with line break	$X\ldots$ $+ Y$	**[Ctrl][↵]**	Same as addition. Line break is purely cosmetic.
Greater than	$x > y$, $S1 > S2$	**>**	For real scalars x and y, returns 1 if $x > y$, 0 otherwise. For string expressions $S1$ and $S2$, returns 1 if $S1$ strictly follows $S2$ in ASCII order, 0 otherwise.
Less than	$x < y$, $S1 < S2$	**<**	For real scalars x and y, returns 1 if $x < y$, 0 otherwise. For string expressions $S1$ and $S2$, returns 1 if $S1$ strictly precedes $S2$ in ASCII order, 0 otherwise.
Greater than or equal	$x \geq y$, $S1 \geq S2$	**[Ctrl]0**	For real scalars x and y, returns 1 if $x \geq y$, 0 otherwise. For string expressions $S1$ and $S2$, returns 1 if $S1$ follows $S2$ in ASCII order, 0 otherwise.
Less than or equal	$x \leq y$, $S1 \leq S2$	**[Ctrl]9**	For real scalars x and y, returns 1 if $x \leq y$, 0 otherwise. For string expressions $S1$ and $S2$, returns 1 if $S1$ precedes $S2$ in ASCII order, 0 otherwise.
Not equal to	$z \neq w$, $S1 \neq S2$	**[Ctrl]3**	For scalars z and w, returns 1 if $z \neq w$, 0 otherwise.For string expressions $S1$ and $S2$, returns 1 if $S1$ is not character by character identical to $S2$.
Equal to	$X = Y$	**[Ctrl]=**	Returns 1 if $X = Y$, 0 otherwise. Appears as a bold = on the screen.

Symbolic transformation functions

Some symbolic transformations (see Chapter 14) are given in terms of functions that aren't among Mathcad's built-in functions. The list below gives definitions for those special functions. Except for *Ei*, *erf*, and *Zeta*, which involve infinite sums, and *W*, you can use these definitions to calculate numerical values.

You can define many of these functions in Mathcad. See the "Other Special Functions" topic in the QuickSheets of the Resource Center for examples.

γ is Euler's constant, approximately 0.5772156649.

$$\mathrm{Chi}(x) = \gamma + \ln(x) + \int_0^x \frac{\cosh(t) - 1}{t}\,dt$$

$$\mathrm{Ci}(x) = \gamma + \ln(x) + \int_0^x \frac{\cos(t) - 1}{t}\,dt$$

$$\mathrm{dilog}(x) = \int_1^x \frac{\ln(t)}{1 - t}\,dt$$

$$\mathrm{Dirac}(x) = 0 \text{ if } x \text{ is not zero. } \int_{-\infty}^{\infty} Dirac(x)\,dx = 1$$

$$\mathrm{Ei}(x) = \gamma + \ln(x) + \sum_{n=1}^{\infty} \frac{x^n}{n \cdot n!} \quad (x > 0)$$

$$\mathrm{erf}(x) = \frac{2}{\sqrt{\pi}} \sum_{n=0}^{\infty} \frac{(-1)^n z^{2n+1}}{n!(2n+1)} \quad \text{(for complex } z\text{)}$$

$$\mathrm{FresnelC}(x) = \int_0^x \cos\left(\frac{\pi}{2} t^2\right) dt$$

$$\mathrm{FresnelS}(x) = \int_0^x \sin\left(\frac{\pi}{2} t^2\right) dt$$

$$\mathrm{LegendreE}(x, k) = \int_0^x \left(\frac{1 - k^2 \cdot t^2}{1 - t^2}\right)^{1/2} dt$$

$$\mathrm{LegendreEc}(k) = \mathrm{LegendreE}(1, k)$$

$$\text{LegendreEc1}(k) = \text{LegendreEc}(\sqrt{1-k^2})$$

$$\text{LegendreF}(x, k) = \int_0^x \frac{1}{\sqrt{(1-t^2)(1-k^2\cdot t^2)}}dt$$

$$\text{LegendreKc}(k) = \text{LegendreF}(1, k)$$

$$\text{LegendreKc1}(k) = \text{LegendreKc}(\sqrt{1-k^2})$$

$$\text{LegendrePi}(x, n, k) = \int_0^x \frac{1}{\sqrt{(1-n^2\cdot t^2)}\sqrt{(1-t^2)(1-k^2\cdot t^2)}}dt$$

$$\text{LegendrePic}(n, k) = \text{LegendrePi}(1, n, k)$$

$$\text{LegendrePic1}(k) = \text{LegendrePic}(n, \sqrt{1-k^2})$$

$$\text{Psi}(n, k) = \frac{d^n}{dx^n}\text{Psi}(x)$$

$$\text{Psi}(x) = \frac{d}{dx}\ln(\Gamma(x))$$

$$\text{Shi}(x) = \int_0^x \frac{\sinh(t)}{t}dt$$

$$\text{Si}(x) = \int_0^x \frac{\sin(t)}{t}dt$$

$W(x)$ is the principal branch of a function satisfying $W(x)\cdot\exp(W(x)) = x$. $W(n, x)$ is the nth branch of $W(x)$.

$$Zeta(s)\left(\sum_{n=1}^{\infty}\frac{1}{n^s}\right) \quad (s > 1)$$

The functions *arcsec, arccsc, arccot, arcsech, arcscsh, arccoth* can be calculated by taking reciprocals and using the Mathcad built-in functions *acos*, *asin*, etc. For example:

$$\text{arcsec}(x) := \text{acos}\left(\frac{1}{x}\right)$$

The *Psi* function and Γ appear frequently in the results of *indefinite* sums and products.

SI units

Base units

m (meter), *length* | kg (kilogram), *mass* | s (second), *time*

A (ampere), *current* | K (kelvin), *temperature* | cd (candela), *luminosity*

mole, *substance*

Angular measure

$rad = 1$ | $deg = \frac{\pi}{180} \cdot rad$ | $str = 1 \cdot str$

Length

$cm = 0.01 \cdot m$ | $km = 1000 \cdot m$ | $mm = 0.001 \cdot m$

$ft = 0.3048 \cdot m$ | $in = 2.54 \cdot cm$ | $yd = 3 \cdot ft$

$mi = 5280 \cdot ft$

Mass

$gm = 10^{-3} \cdot kg$ | $tonne = 1000 \cdot kg$ | $lb = 453.59237 \cdot gm$

$mg = 10^{-3} \cdot gm$ | $ton = 2000 \cdot lb$ | $slug = 32.174 \cdot lb$

$oz = \frac{lb}{16}$

Time

$min = 60 \cdot s$ | $hr = 3600 \cdot s$ | $day = 24 \cdot hr$

$yr = 365.2422 \cdot day$

Area, Volume

$hectare = 10^4 \cdot m^2$ | $acre = 4840 \cdot yd^2$ | $L = 0.001 \cdot m^3$

$mL = 10^{-3} \cdot L$ | $fl\_oz = 29.57353 \cdot cm^3$ | $gal = 128 \cdot fl\_oz$

Velocity, Acceleration

$mph = \frac{mi}{hr}$ | $kph = \frac{km}{hr}$ | $g = 9.80665 \cdot \frac{m}{s^2}$

Force, Energy, Power

$N = kg \cdot \frac{m}{s^2}$ | $dyne = 10^{-5} \cdot N$ | $lbf = g \cdot lb$

$kgf = g \cdot kg$ | $J = N \cdot m$ | $erg = 10^{-7} \cdot J$

$cal = 4.1868 \cdot J$ | $kcal = 1000 \cdot cal$ | $BTU = 1.05506 \cdot 10^3 \cdot J$

$W = \frac{J}{s}$ | $kW = 1000 \cdot W$ | $hp = 550 \cdot \frac{ft \cdot lbf}{s}$

Pressure, Viscosity

$Pa = \frac{N}{m^2}$ $psi = \frac{lbf}{in^2}$ $atm = 1.01325 \cdot 10^5 \cdot Pa$

$in\_Hg = 3.38638 \cdot 10^3 \cdot Pa$ $torr = 1.33322 \cdot 10^2 \cdot Pa$ $stokes = 10^{-4} \cdot \frac{m^2}{s}$

$poise = 0.1 \cdot Pa \cdot s$

Electrical

$C = A \cdot s$ $V = \frac{J}{C}$ $mV = 10^{-3} \cdot V$

$KV = 10^3 \cdot V$ $\Omega = \frac{V}{A}$ $k\Omega = 10^3 \cdot \Omega$

$M\Omega = 10^6 \cdot \Omega$ $S = \frac{1}{\Omega}$ $mho = \frac{1}{\Omega}$

$H = \frac{V}{A} \cdot s$ $\mu H = 10^{-6} \cdot H$ $mH = 10^{-3} \cdot H$

$\mu A = 10^{-6} \cdot A$ $mA = 10^{-3} \cdot A$ $kA = 10^3 \cdot A$

$F = \frac{C}{V}$ $pF = 10^{-12} \cdot F$ $nF = 10^{-9} \cdot F$

$\mu F = 10^{-6} \cdot F$ $Wb = V \cdot s$

$Oe = \frac{1000}{4 \cdot \pi} \cdot \frac{A}{m}$ $T = \frac{Wb}{m^2}$ $gauss = 10^{-4} \cdot T$

Frequency, Activity

$Hz = \frac{1}{s}$ $kHz = 10^3 \cdot Hz$ $MHz = 10^6 \cdot Hz$

$GHz = 10^9 \cdot Hz$ $Bq = \frac{1}{s}$

Temperature

$R = 0.556 \cdot K$

Dose

$Gy = \frac{J}{kg}$ $Sv = \frac{J}{kg}$

Luminous flux, illuminance

$lm = cd \cdot str$ $lx = \frac{cd \cdot str}{m^2}$

CGS units

Base units

cm (centimeter), *length*

gm (gram), *mass*

sec (second), *time*

coul (coulomb), *charge*

K (kelvin), *temperature*

Angular measure

$rad = 1$

$deg = \frac{\pi}{180} \cdot rad$

Length

$m = 100 \cdot cm$

$km = 1000 \cdot m$

$mm = 0.1 \cdot cm$

$ft = 30.48 \cdot cm$

$in = 2.54 \cdot cm$

$yd = 3 \cdot ft$

$mi = 5280 \cdot ft$

Mass

$kg = 1000 \cdot gm$

$tonne = 1000 \cdot kg$

$lb = 453.59237 \cdot gm$

$mg = 10^{-3} \cdot gm$

$ton = 2000 \cdot lb$

$slug = 32.174 \cdot lb$

$oz = \frac{lb}{16}$

Time

$min = 60 \cdot sec$

$hr = 3600 \cdot sec$

$day = 24 \cdot hr$

$yr = 365.2422 \cdot day$

Area, Volume

$hectare = 10^4 \cdot m^2$

$acre = 4840 \cdot yd^2$

$liter = 1000 \cdot cm^3$

$mL = cm^3$

$fl\_oz = 29.57353 \cdot cm^3$

$gal = 128 \cdot fl\_oz$

Velocity, Acceleration

$mph = \frac{mi}{hr}$

$kph = \frac{km}{hr}$

$g = 980.665 \cdot \frac{cm}{sec^2}$

$c = 2.997925 \cdot 10^{10} \cdot \frac{cm}{sec}$

$c\_ = c \cdot \frac{sec}{m}$

Force, Energy, Power

$dyne = gm \cdot \frac{cm}{sec^2}$ $\quad newton = 10^5 \cdot dyne$ $\quad lbf = g \cdot lb$

$kgf = g \cdot kg$ $\quad erg = dyne \cdot cm$ $\quad joule = 10^7 \cdot erg$

$cal = 4.1868 \cdot 10^7 \cdot erg$ $\quad BTU = 1.05506 \cdot 10^{10} \cdot erg$ $\quad kcal = 1000 \cdot cal$

$watt = \frac{joule}{sec}$ $\quad kW = 1000 \cdot watt$ $\quad hp = 550 \cdot \frac{ft \cdot lbf}{sec}$

Pressure, Viscosity

$Pa = 10 \cdot \frac{dyne}{cm^2}$ $\quad psi = \frac{lbf}{in^2}$ $\quad atm = 1.01325 \cdot 10^5 \cdot Pa$

$in\_Hg = 3.38638 \cdot 10^3 \cdot Pa$ $\quad torr = 1.33322 \cdot 10^2 \cdot Pa$ $\quad stokes = \frac{cm^2}{sec}$

$poise = 0.1 \cdot Pa \cdot sec$

Electrical

These are CGS-esu units, based only on mass, length, and time. The “stat” units are defined in terms of dyne, cm, and sec.

$statamp = dyne^{0.5} \cdot cm \cdot sec^{-1}$ $\quad statcoul = dyne^{0.5} \cdot cm$ $\quad statvolt = dyne^{0.5}$

$statohm = sec \cdot cm^{-1}$ $\quad statsiemens = cm \cdot sec^{-1}$ $\quad statfarad = cm$

$statweber = dyne^{0.5} \cdot cm$ $\quad stathenry = sec^2 \cdot cm^{-1}$ $\quad statesla = dyne^{0.5} \cdot cm \cdot sec^{-2}$

Frequency

$Hz = \frac{1}{sec}$ $\quad KHz = 10^3 \cdot Hz$ $\quad MHz = 10^6 \cdot Hz$

$GHz = 10^9 \cdot Hz$

Temperature

$R = 0.556 \cdot K$

Conversions to SI Units

$amp = \frac{c}{10} \cdot statamp$ $\quad volt = \frac{watt}{amp}$ $\quad ohm = \frac{volt}{amp}$

$coul = amp \cdot sec$ $\quad farad = \frac{coul}{volt}$ $\quad henry = volt \cdot \frac{sec}{amp}$

U.S. customary units

Base units

ft (foot), *length*

lb (pound), *mass*

sec (second), *time*

coul (coulomb), *charge*

K (kelvin), *temperature*

Angular measure

$rad = 1$

$deg = \frac{\pi}{180} \cdot rad$

Length

$in = \frac{ft}{12}$

$m = \frac{ft}{0.3048}$

$yd = 3 \cdot ft$

$cm = 0.01 \cdot m$

$mi = 5280 \cdot ft$

$km = 1000 \cdot m$

$mm = 0.001 \cdot m$

Mass

$slug = 32.174 \cdot lb$

$oz = \frac{lb}{16}$

$ton = 2000 \cdot lb$

$kg = \frac{lb}{0.45359237}$

$tonne = 1000 \cdot kg$

$gm = 10^{-3} \cdot kg$

$mg = 10^{-3} \cdot gm$

Time

$min = 60 \cdot sec$

$hr = 3600 \cdot sec$

$day = 24 \cdot hr$

$yr = 365.2422 \cdot day$

Area, Volume

$acre = 4840 \cdot yd^2$

$hectare = 10^4 \cdot m^2$

$fl\_oz = 29.57353 \cdot cm^3$

$liter = (0.1 \cdot m)^2$

$mL = 10^{-3} \cdot liter$

$gal = 128 \cdot fl\_oz$

Velocity, Acceleration

$mph = \frac{mi}{hr}$

$kph = \frac{km}{hr}$

$g = 32.174 \cdot \frac{ft}{sec^2}$

Force, Energy, Power

$lbf = g \cdot lb$

$newton = kg \cdot \frac{m}{sec^2}$

$dyne = 10^{-5} \cdot newton$

$kgf = g \cdot kg$

$joule = newton \cdot m$

$erg = 10^{-7} \cdot joule$

$cal = 4.1868 \cdot joule$

$kcal = 1000 \cdot cal$

$BTU = 1.05506 \cdot 10^3 \cdot joule$

$watt = \frac{joule}{sec}$

$hp = 550 \cdot \frac{ft \cdot lbf}{sec}$

$kW = 1000 \cdot watt$

Pressure, Viscosity

$psi = \frac{lbf}{in^2}$ $Pa = \frac{newton}{m^2}$ $atm = 1.01325 \cdot 10^5 \cdot Pa$

$in\_Hg = 3.38638 \cdot 10^3 \cdot Pa$ $torr = 1.33322 \cdot 10^2 \cdot Pa$ $stokes = \frac{cm^2}{sec}$

$poise = 0.1 \cdot Pa \cdot sec$

Electrical

$volt = \frac{watt}{amp}$ $mV = 10^{-3} \cdot volt$ $KV = 10^3 \cdot volt$

$ohm = \frac{volt}{amp}$ $mho = \frac{1}{ohm}$ $siemens = \frac{1}{ohm}$

$\Omega = ohm$ $K\Omega = 10^3 \cdot ohm$ $M\Omega = 10^6 \cdot ohm$

$henry = \frac{weber}{amp}$ $\mu H = 10^{-6} \cdot henry$ $mH = 10^{-3} \cdot henry$

$amp = \frac{coul}{sec}$ $\mu A = 10^{-6} \cdot amp$ $mA = 10^{-3} \cdot amp$

$KA = 10^3 \cdot amp$ $farad = \frac{coul}{volt}$ $pF = 10^{-12} \cdot farad$

$nF = 10^{-9} \cdot farad$ $\mu F = 10^{-6} \cdot farad$ $weber = volt \cdot sec$

$oersted = \frac{1000}{4 \cdot \pi} \cdot \frac{amp}{m}$ $tesla = \frac{weber}{m^2}$ $gauss = 10^{-4} \cdot tesla$

Frequency

$Hz = \frac{1}{sec}$ $KHz = 10^3 \cdot Hz$ $MHz = 10^6 \cdot Hz$

$GHz = 10^9 \cdot Hz$

Temperature

$R = 0.556 \cdot K$

MKS units

Base units

m (meter), *length*

kg (kilogram), *mass*

sec (second), *time*

coul (coulomb), *charge*

K (kelvin), *temperature*

Angular measure

$rad = 1$

$deg = \frac{\pi}{180} \cdot rad$

Length

$cm = 0.01 \cdot m$

$km = 1000 \cdot m$

$mm = 0.001 \cdot m$

$ft = 0.3048 \cdot m$

$in = 2.54 \cdot cm$

$yd = 3 \cdot ft$

$mi = 5280 \cdot ft$

Mass

$gm = 10^{-3} \cdot kg$

$tonne = 1000 \cdot kg$

$lb = 453.59237 \cdot gm$

$mg = 10^{-3} \cdot gm$

$ton = 2000 \cdot lb$

$slug = 32.174 \cdot lb$

$oz = \frac{lb}{16}$

Time

$min = 60 \cdot sec$

$hr = 3600 \cdot sec$

$day = 24 \cdot hr$

$yr = 365.2422 \cdot day$

Area, Volume

$hectare = 10^4 \cdot m^2$

$acre = 4840 \cdot yd^2$

$liter = (0.1 \cdot m)^3$

$mL = 10^{-3} \cdot liter$

$fl\_oz = 29.57353 \cdot cm^3$

$gal = 128 \cdot fl\_oz$

Velocity, Acceleration

$mph = \frac{mi}{hr}$

$kph = \frac{km}{hr}$

$g = 9.80665 \cdot \frac{m}{sec^2}$

Force, Energy, Power

$newton = kg \cdot \frac{m}{sec^2}$

$dyne = 10^{-5} \cdot newton$

$lbf = g \cdot lb$

$kgf = g \cdot kg$

$joule = newton \cdot m$

$erg = 10^{-7} \cdot joule$

$cal = 4.1868 \cdot joule$

$kcal = 1000 \cdot cal$

$BTU = 1.05506 \cdot 10^3 \cdot joule$

$watt = \frac{joule}{sec}$

$kW = 1000 \cdot watt$

$hp = 550 \cdot \frac{ft \cdot lbf}{sec}$

Pressure, Viscosity

$Pa = \frac{newton}{m^2}$ $psi = \frac{lbf}{in^2}$ $atm = 1.01325 \cdot 10^5 \cdot Pa$

$in\_Hg = 3.38638 \cdot 10^3 \cdot Pa$ $torr = 1.33322 \cdot 10^2 \cdot Pa$ $stokes = 10^{-4} \cdot \frac{m^2}{sec}$

$poise = 0.1 \cdot Pa \cdot sec$

Electrical

$volt = \frac{watt}{amp}$ $mV = 10^{-3} \cdot volt$ $KV = 10^3 \cdot volt$

$ohm = \frac{volt}{amp}$ $mho = \frac{1}{ohm}$ $siemens = \frac{1}{ohm}$

$\Omega = ohm$ $K\Omega = 10^3 \cdot ohm$ $M\Omega = 10^6 \cdot ohm$

$henry = \frac{weber}{amp}$ $\mu H = 10^{-6} \cdot henry$ $mH = 10^{-3} \cdot henry$

$amp = \frac{coul}{sec}$ $\mu A = 10^{-6} \cdot amp$ $mA = 10^{-3} \cdot amp$

$KA = 10^3 \cdot amp$ $farad = \frac{coul}{volt}$ $pF = 10^{-12} \cdot farad$

$nF = 10^{-9} \cdot farad$ $\mu F = 10^{-6} \cdot farad$ $weber = volt \cdot sec$

$oersted = \frac{1000}{4 \cdot \pi} \cdot \frac{amp}{m}$ $tesla = \frac{weber}{m^2}$ $gauss = 10^{-4} \cdot tesla$

Frequency

$Hz = \frac{1}{sec}$ $KHz = 10^3 \cdot Hz$ $MHz = 10^6 \cdot Hz$

$GHz = 10^9 \cdot Hz$

Temperature

$R = 0.556 \cdot K$

Predefined variables

Mathcad's predefined variables are listed here with their default starting values.

	Constant=Value	Meaning
	$\pi = 3.14159...$	Pi. Mathcad uses the value of π to 15 digits. To type π, press [**Ctrl**]**p**.
	$e = 2.71828...$	The base of natural logarithms. Mathcad uses the value of *e* to 15 digits.
	$\infty = 10^{307}$	Infinity. This symbol represents values larger than the largest real number representable in Mathcad (about 10^{307}). To type ∞, press [**Ctrl**][**Shift**]**Z**.
	$\% = 0.01$	Percent. Use in expressions like **10*%** (appears as $10 \cdot \%$) or as a scaling unit at the end of an equation with an equal sign.
	CTOL = 10^{-3}	Constraint tolerance used in solving and optimization functions: how closely a constraint must be met for a solution to be considered acceptable. For more information, see "Solving and optimization functions" on page 187.
Pro	**CWD** = "[system path]"	String corresponding to the working folder of the worksheet.
	FRAME = 0	Counter for creating animation clips.
Pro	**in***n* = 0, **out***n* = 0	Input and output variables (**in0**, **in1**, **out0**, **out1**, etc.) in a Mathcad component in a MathConnex system. See the *MathConnex User's Guide* for details.
	ORIGIN = 0	Array origin. Specifies the index of the first element in arrays.
	PRNCOLWIDTH = 8	Column width used in writing files with *WRITEPRN* function.
	PRNPRECISION = 4	Number of significant digits used when writing files with the *WRITEPRN* function.
	TOL = 10^{-3}	Tolerance used in numerical approximation algorithms (integrals, equation solving, etc.): how close successive approximations must be for a solution to be returned. For more information, see the sections on the specific operation in question.

Suffixes for numbers

The table below shows how Mathcad interprets numbers (sequences of letters beginning with a digit) that end with a letter.

Suffix	Example	Meaning
b	100001b	Binary
i *or* j	4i, 1j, 3 + 1.5j	Imaginary
h	8BCh	Hexadecimal
K	–273K	Standard absolute temperature unit
L	–2.54L	Standard length unit
M	2.2M	Standard mass unit
o	1007o	Octal
Q	–100Q	Standard charge unit
S	6.97S	Standard substance unit in SI unit system
T	3600T	Standard time unit
U	125U	Standard luminosity unit in SI unit system

Note Because Mathcad by default treats most expressions involving a number followed immediately by a letter to mean implied multiplication of a number by a variable name, you will need to backspace over the implied multiplication operator to create expressions like **4.5M**.

Greek letters

To type a Greek letter into an equation or into text, press the Roman equivalent from the table below, followed by [**Ctrl**]**G**. Alternatively, use the Greek toolbar.

Name	Uppercase	Lowercase	Roman equivalent
alpha	Α	α	A
beta	Β	β	B
chi	Χ	χ	C
delta	Δ	δ	D
epsilon	Ε	ε	E
eta	Η	η	H
gamma	Γ	γ	G
iota	Ι	ι	I
kappa	Κ	κ	K
lambda	Λ	λ	L
mu	Μ	μ	M
nu	Ν	ν	N
omega	Ω	ω	W
omicron	Ο	ο	O
phi	Φ	ϕ	F
phi (alternate)		φ	J
pi	Π	π	P
psi	Ψ	ψ	Y
rho	Ρ	ρ	R
sigma	Σ	σ	S
tau	Τ	τ	T
theta	Θ	θ	Q
theta (alternate)	ϑ		J
upsilon	Υ	υ	U
xi	Ξ	ξ	X
zeta	Ζ	ζ	Z

Note The Greek letter π is so commonly used that it has its own keyboard shortcut: [**Ctrl**][**Shift**]**P**.

Function keys

Keys	Actions
[**F1**]	Help.
[**Shift**][**F1**]	Context sensitive help.
[**F2**]	Copy selected region to clipboard.
[**F3**]	Cut selected region to clipboard.
[**F4**]	Paste contents of clipboard.
[**Ctrl**][**F4**]	Close worksheet or template.
[**F5**]	Open a worksheet or template.
[**Ctrl**][**F5**]	Search for text or math characters.
[**Shift**][**F5**]	Replace text or math characters.
[**F6**]	Save current worksheet.
[**Ctrl**][**F6**]	Make next window active.
[**F7**]	Open a new worksheet.
[**F9**]	Recalculate everything on the screen. With *READ*, *WRITE* or other file I/O function selected, forces Mathcad to read or write to disk.

Note These function keys are provided mainly for compatibility with earlier Mathcad versions. Mathcad also supports standard Windows keystrokes for operations such as file opening ([**Ctrl**]**O**]) and saving ([**Ctrl**]**S**]), copying([**Ctrl**]**C**]), and pasting ([**Ctrl**]**V**]). Choose **Preferences** from the **View** menu and check "Use standard Windows shortcut keys" on the General tab to enable all Windows shortcuts.

Arrow and movement keys

Keys	Actions
[↑]	Move crosshair up. In math: move editing lines up. In text: move insertion point up to previous line.
[↓]	Move crosshair down. In math: move editing lines down. In text: move insertion point down to next line.
[←]	Move crosshair left. In math: select left operand. In text: move insertion point one character to the left.
[→]	Move crosshair right. In math: select right operand. In text: move insertion point one character to the right.
[**PgUp**]	Scroll up about one-fourth the height of the window.
[**PgDn**]	Scroll down about one-fourth the height of the window.
[**Shift**][↑]	In math: move crosshair outside and above equation. In text: highlight from insertion point up to previous line.
[**Shift**][↓]	In math: move crosshair outside and below equation. In text: highlight from insertion point down to next line.
[**Shift**][←]	In math: move crosshair outside and to the left of equation. In text: highlight to left of insertion point, character by character.
[**Shift**][→]	In math: move crosshair outside and to the right of equation. In text: highlight to right of insertion point, character by character.
[**Shift**][**PgUp**]	Position preceding page break at top of the window.
[**Shift**][**PgDn**]	Position next page break at top of the window.
[**Ctrl**][↑]	In text: move insertion point to the beginning of a line.
[**Ctrl**][↓]	In text: move insertion point to the beginning of next line.
[**Ctrl**][←]	In text: move insertion point left to the beginning of a word.
[**Ctrl**][→]	In text: move insertion point to the beginning of next word.
[**Ctrl**][**Home**]	Move crosshair to first region in worksheet.
[**Ctrl**][**End**]	Move crosshair to last region in worksheet.
[**Ctrl**][**Enter**]	Insert a hard page break. In math: insert addition with line break operator. In text: set the width of the text region.
[**Ctrl**][**Shift**][↑]	In text: highlight from insertion point up to the beginning of a line.
[**Ctrl**][**Shift**][↓]	In text: highlight from insertion point to end of the current line.
[**Ctrl**][**Shift**][←]	Highlight left from insertion point to the beginning of a word.
[**Ctrl**][**Shift**][→]	Highlight from insertion point to beginning of the next word.

Keys	Actions
[**Space**]	In math: cycles through different states of the editing lines.
[**Tab**]	In text: inserts a five-character space. In math or plot: move to next placeholder.
[**Shift**][**Tab**]	In math or plot: move to previous placeholder.
[**PgUp**]	Move up 5 lines.
[**PgDn**]	Move down 5 lines.
[**Ctrl**][**PgUp**]	Move 80% up the window.
[**Ctrl**][**PgDn**]	Move 80% down the window.
[**Shift**][**PgUp**]	Move up to previous pagebreak.
[**Shift**][**PgDn**]	Move down to next pagebreak.
[**Home**]	Move to beginning of previous region. In text, move to beginning of current line.
[**End**]	Move to next region. In text, move to end of current line.
[**Ctrl**][**Home**]	Scroll to beginning of worksheet. In text, move insertion point to beginning of text region or paragraph.
[**Ctrl**][**End**]	Scroll to end of worksheet. In text, move insertion point to end of text region or paragraph.
[↵]	In text: start new line. In equation or plot: move crosshair below region, even with left edge of region.

ASCII codes

Decimal ASCII codes from 32 to 255. Nonprinting characters are indicated by "*npc*."

Code	Character	Code	Character	Code	Character	Code	Character	Code	Character
32	[space]	80	P	130	‚	182	¶	230	æ
33	!	81	Q	131	*f*	183	·	231	ç
34	"	82	R	132	„	184	¸	232	è
35	#	83	S	133	...	185	¹	233	é
36	$	84	T	134	†	186	º	234	ê
37	%	85	U	135	‡	187	»	235	ë
38	&	86	V	136	ˆ	188	¼	236	ì
39	'	87	W	137	‰	189	½	237	í
40	(	88	X	138	Š	190	¾	238	î
41	)	89	Y	139	‹	191	¿	239	ï
42	*	90	Z	140	Œ	192	À	240	ð
43	+	91	[	141–4	*npc*	193	Á	241	ñ
44	,	92	\	145	‘	194	Â	242	ò
45	-	93	]	146	’	195	Ã	243	ó
46	.	94	^	147	“	196	Ä	244	ô
47	/	95	_	148	”	197	Å	245	õ
48	0	96	`	149	•	198	Æ	246	ö
49	1	97	a	150	–	199	Ç	247	÷
50	2	98	b	151	—	200	È	248	ø
51	3	99	c	152	˜	201	É	249	ù
52	4	100	d	153	™	202	Ê	250	ú
53	5	101	e	154	š	203	Ë	251	û
54	6	102	f	155	›	204	Ì	252	ü
55	7	103	g	156	œ	205	Í	253	ý
56	8	104	h	157–8	*npc*	206	Î	254	þ
57	9	105	i	159	Ÿ	207	Ï	255	ÿ
58	:	106	j	160	*npc*	208	Ð		
59	;	107	k	161	¡	209	Ñ		
60	<	108	l	162	¢	210	Ò		
61	=	109	m	163	£	211	Ó		
62	>	110	n	164	¤	212	Ô		
63	?	111	o	165	¥	213	Õ		
64	@	112	p	166	¦	214	Ö		
65	A	113	q	167	§	215	×		
66	B	114	r	168	¨	216	Ø		
67	C	115	s	169	©	217	Ù		
68	D	116	t	170	ª	218	Ú		
69	E	117	u	171	«	219	Û		
70	F	118	v	172	¬	220	Ü		
71	G	119	w	173	-	221	Ý		
72	H	120	x	174	®	222	Þ		
73	I	121	y	175	¯	223	ß		
74	J	122	z	176	°	224	à		
75	K	123	{	177	±	225	á		
76	L	124	|	178	²	226	â		
77	M	125	}	179	³	227	ã		
78	N	126	~	180	´	228	ä		
79	O	127–9	*npc*	181	µ	229	å		