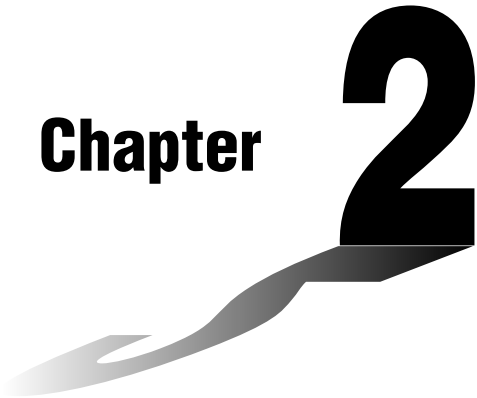

Manual Calculations

2-1 Basic Calculations

■ Arithmetic Calculations

- Enter arithmetic calculations as they are written, from left to right.
- Use the (−) key to input the minus sign before a negative value.
- Calculations are performed internally with a 15-digit mantissa. The result is rounded to a 10-digit mantissa before it is displayed.
- For mixed arithmetic calculations, multiplication and division are given priority over addition and subtraction.

Example	Operation
23 + 4.5 – 53 = –25.5	**23** [+] **4.5** [−] **53** [EXE]
56 × (–12) ÷ (–2.5) = 268.8	**56** [×] (−) **12** [÷] (−) **2.5** [EXE]
$(2 + 3) \times 10^2 = 500$	[(] **2** [+] **3** [)] [×] **1** [EXP] **2** [EXE] *1
$1 + 2 - \underline{3 \times 4 \div 5} + 6 = 6.6$	**1** [+] **2** [−] **3** [×] **4** [÷] **5** [+] **6** [EXE]
100 – (2 + 3) × 4 = 80	**100** [−] [(] **2** [+] **3** [)] [×] **4** [EXE]
2 + 3 × (4 + 5) = 29	**2** [+] **3** [×] [(] **4** [+] **5** [EXE] *2
(7 – 2) × (8 + 5) = 65	[(] **7** [−] **2** [)] [(] **8** [+] **5** [)] [EXE] *3
$\frac{6}{4 \times 5} = 0.3$	**6** [÷] [(] **4** [×] **5** [)] [EXE] *4
$(1 + 2i) + (2 + 3i) = 3 + 5i$	[(] [1] [+] [2] [SHIFT] [0] (*i*) [)] [+] [(] [2] [+] [3] [SHIFT] [0] (*i*) [)] [EXE]
$(2 + i) \times (2 - i) = 5$	[(] [2] [+] [SHIFT] [0] (*i*) [)] [×] [(] [2] [−] [SHIFT] [0] (*i*) [)] [EXE]

*1 [(] 2 [+] 3 [)] [EXP] 2 does not produce the correct result. Be sure to enter this calculation as shown.

*2 Final closed parentheses (immediately before operation of the [EXE] key) may be omitted, no matter how many are required.

*3 A multiplication sign immediately before an open parenthesis may be omitted.

*4 This is identical to 6 [÷] 4 [÷] 5 [EXE].

■ Number of Decimal Places, Number of Significant Digits, Normal Display Range

[SET UP]-[Display]-[Fix]/[Sci]/[Norm]

- Even after you specify the number of decimal places or the number of significant digits, internal calculations are still performed using a 15-digit mantissa, and displayed values are stored with a 10-digit mantissa. Use Rnd of the Numeric Calculation Menu (NUM) (page 2-4-1) to round the displayed value off to the number of decimal place and significant digit settings.
- Number of decimal place (Fix) and significant digit (Sci) settings normally remain in effect until you change them or until you change the normal display range (Norm) setting.

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Example **100 ÷ 6 = 16.66666666...**

Condition	Operation	Display
	100 ÷ 6 EXE	**16.66666667**
4 decimal places	CTRL F3 (SET UP) ▼▼▼▼▼▼▼▼▼▼ F1 (Fix) 4 EXE ESC EXE	**16.6667** *1
5 significant digits	CTRL F3 (SET UP) ▼▼▼▼▼▼▼▼▼▼ F2 (Sci) 5 EXE ESC EXE	**1.6667E+01** *1
Cancels specification	CTRL F3 (SET UP) ▼▼▼▼▼▼▼▼▼▼ F3 (Norm) ESC EXE	**16.66666667**

*1 Displayed values are rounded off to the place you specify.

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Example **200 ÷ 7 × 14 = 400**

Condition	Operation	Display
3 decimal places	**200** ÷ **7** × **14** EXE CTRL F3 (SET UP) ▼▼▼▼▼▼▼▼▼▼ F1 (Fix) **3** EXE ESC EXE	**400** **400.000**
Calculation continues using display capacity of 10 digits	**200** ÷ **7** EXE × **14** EXE	**28.571** **Ans** × [ ] **400.000**

• If the same calculation is performed using the specified number of digits:

The value stored internally is rounded off to the number of decimal places you specify.	**200** ÷ **7** EXE OPTN F5 (NUM) **4** (Rnd) EXE × **14** EXE	**28.571** **28.571** **Ans** × [ ] **399.994**

■ Calculation Priority Sequence

This calculator employs true algebraic logic to calculate the parts of a formula in the following order:

① Coordinate transformation Pol (x, y), Rec (r, θ)

Differentials, quadratic differentials, integrations, Σ calculations

d/dx, d^2/dx^2, $\int dx$, Σ, Mat, Solve, FMin, FMax, List→Mat, Seq, Min, Max, Median, Mean, Augment, Mat→List, P(, Q(, R(, t(, List

Composite functions*1 fn, **Y**n, **r**n, **X**tn, **Y**tn, **X**n

② Type A functions

With these functions, the value is entered and then the function key is pressed.

x^2, x^{-1}, $x!$, ° ' ", ENG symbols, angle unit $^{\circ}$, ^{r}, ^{g}

*1 You can combine the contents of multiple function memory (fn) locations or graph memory (**Y**n, **r**n, **X**tn, **Y**tn, **X**n) locations into composite functions. Specifying fn1(fn2), for example, results in the composite function fn1∘fn2 (see page 5-3-3).
A composite function can consist of up to five functions.

③ Power/root ^(x^y), $\sqrt[x]{\ }$

④ Fractions $a\frac{b}{c}$

⑤ Abbreviated multiplication format in front of π, memory name, or variable name.

2π, 5A, Xmin, F Start, etc.

⑥ Type B functions

With these functions, the function key is pressed and then the value is entered.

$\sqrt{\ }$, $\sqrt[3]{\ }$, log, ln, e^x, 10^x, sin, cos, tan, $\sin^{-1}$, $\cos^{-1}$, $\tan^{-1}$, sinh, cosh, tanh, $\sinh^{-1}$, $\cosh^{-1}$, $\tanh^{-1}$, (–), d, h, b, o, Neg, Not, Det, Trn, Dim, Identity, Sum, Prod, Cuml, Percent, ∠List, Abs, Int, Frac, Intg, Arg, Conjg, ReP, ImP

⑦ Abbreviated multiplication format in front of Type B functions

$2\sqrt{3}$, A log2, etc.

⑧ Permutation, combination $_n\mathrm{P}_r$, $_n\mathrm{C}_r$

⑨ ×, ÷

⑩ +, –

⑪ Relational operators >, <, ≥, ≤

⑫ Relational operators =, ≠

⑬ and (bitwise operation)

⑭ xnor, xor (bitwise operations)

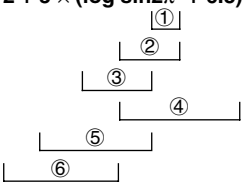
⑮ or (bitwise operation)

⑯ And (logical operation)

⑰ Or (logical operation)

● ● ● ● ●

Example **$2 + 3 \times (\log \sin 2\pi^2 + 6.8) = 22.07101691$ (angle unit = Rad)**



When functions with the same priority are used in series, execution is performed from right to left.
$e^x \ln \sqrt{120} \rightarrow e^x\{\ln(\sqrt{120})\}$

Otherwise, execution is from left to right.

Compound functions are executed from right to left.

Anything contained within parentheses receives highest priority.

■ Multiplication Operations without a Multiplication Sign

You can omit the multiplication sign (×) in any of the following operations.

- Before coordinate transformation and Type B functions (① on page 2-1-3 and ⑥ on page 2-1-4), except for negative signs

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Example **2sin30, 10log1.2, 2√, 2Pol(5, 12), etc.**

- Before constants, variable names, memory names

● ● ● ● ●
Example **2π, 2AB, 3Ans, 3Y_1, etc.**

- Before an open parenthesis

● ● ● ● ●
Example **3(5 + 6), (A + 1)(B – 1), etc.**

■ Overflow and Errors

Exceeding a specified input or calculation range, or attempting an illegal input causes an error message to appear on the display. Further operation of the calculator is impossible while an error message is displayed. The following events cause an error message to appear on the display.

- When any result, whether intermediate or final, or any value in memory exceeds $\pm 9.999999999 \times 10^{99}$ (Ma ERROR).
- When an attempt is made to perform a function calculation that exceeds the input range (Ma ERROR).
- When an illegal operation is attempted during statistical calculations (Ma ERROR). For example, attempting to obtain 1VAR without data input.
- When an improper data type is specified for the argument of a function calculation (Ma ERROR).
- When the capacity of the numeric value stack or command stack is exceeded (Stack ERROR). For example, entering 25 successive ((followed by 2 + 3 × 4 EXE.
- When an attempt is made to perform a calculation using an illegal formula (Syntax ERROR). For example, 5 × × 3 EXE.

Other errors can occur during program execution. Most of the calculator's keys are inoperative while an error message is displayed.

Press ESC to clear the error and display the error position (see page 1-3-4).

See the "Error Message Table" on page α-1-1 for information on other errors.

- When you try to perform a calculation that causes memory capacity to be exceeded (Memory ERROR).
- When you use a command that requires an argument, without providing a valid argument (Argument ERROR).
- When an attempt is made to use an illegal dimension during matrix calculations (Dimension ERROR).
- When you are in the real mode and an attempt is made to perform a calculation that produces a complex number solution. Note that "Real" is selected for the Complex Mode setting on the SET UP Screen (Non-Real ERROR).

■ Memory Capacity

Each time you press a key, either one byte or two bytes is used. Some of the functions that require one byte are: [1], [2], [3], sin, cos, tan, log, ln, $\sqrt{\ }$, and π. Some of the functions that take up two bytes are d/dx(, Mat, Xmin, If, For, Return, DrawGraph, SortA(, PxlOn, Sum, and a_{n+1}.

As you input numeric values or commands, they appear flush left on the display. Calculation results, on the other hand, are displayed flush right.

The allowable range for both input and output values is 15 digits for the mantissa and two digits for the exponent. Internal calculations are also performed using a 15-digit mantissa and two-digit exponent.

2-2 Special Functions

■ Calculations Using Variables

Example	Operation	Display
	193.2 → ALPHA X,θ,T (A) EXE	**193.2**
193.2 ÷ 23 = 8.4	ALPHA X,θ,T (A) ÷ **23** EXE	**8.4**
193.2 ÷ 28 = 6.9	ALPHA X,θ,T (A) ÷ **28** EXE	**6.9**

■ Memory

• Variables

This calculator comes with 28 variables as standard. You can use variables to store values you want to use inside of calculations. Variables are identified by single-letter names, which are made up of the 26 letters of the alphabet, plus r and θ. The maximum size of values that you can assign to variables is 15 digits for the exponent.

• To assign a value to a variable

[value] → [variable name] EXE

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Example **To assign 123 to variable A**

AC 1 2 3 → ALPHA X,θ,T (A) EXE

```
123→A
                123
```

● ● ● ● ●

Example **To add 456 to variable A and store the result in variable B**

AC ALPHA X,θ,T (A) + 4 5 6 → ALPHA log (B) EXE

```
A+456→B
                579
```

Variable contents are retained even when you turn power off.

• To display the contents of a variable

● ● ● ● ●

Example **To display the contents of variable A**

AC ALPHA X,θ,T (A) EXE

• To clear a variable

● ● ● ● ●

Example **To clear variable A**

AC 0 → ALPHA X,θ,T (A) EXE

• To assign the same value to more than one variable

[value] → [first variable name*1] OPTN F6 (▷) F6 (▷) F4 (SYBL) 3 (~) [last variable name*1] EXE

● ● ● ● ●

Example **To assign a value of 10 to variables A through F**

AC 1 0 → ALPHA X,θ,T (A)
OPTN F6 (▷) F6 (▷) F4 (SYBL) 3 (~)
ALPHA tan (F) EXE

• Function Memory **[OPTN]-[FMEM]**

Function memory (f_1~f_{20}) is convenient for temporary storage of often-used expressions. For longer term storage, we recommend that you use the GRPH • TBL Mode for expressions and the PRGM Mode for programs.

- {**Store**}/{**Recall**}/{**fn**}/{**SEE**} ... {function store}/{function recall}/{function area specification as a variable name inside an expression}/{function list}

*1 You cannot use "r" or "θ" as a variable name.

• To store a function

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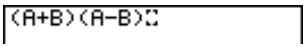
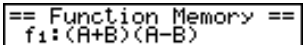
Example **To store the function (A+B) (A–B) as function memory number 1**

(ALPHA X,θ,T (A) + ALPHA log (B))
(ALPHA X,θ,T (A) − ALPHA log (B))



OPTN F6 (▷) F5 (FMEM)
1 (Store) 1 EXE

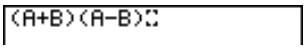


• To recall a function

● ● ● ● ●

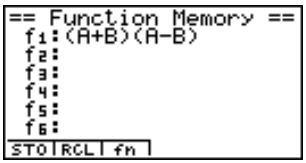
Example **To recall the contents of function memory number 1**

OPTN F6 (▷) F5 (FMEM)
2 (Recall) 1 EXE



• To display a list of available functions

OPTN F6 (▷) F5 (FMEM)
4 (SEE)



If the function memory number to which you store a function already contains a function, the previous function is replaced with the new one.

The recalled function appears at the current location of the cursor on the display.

• To delete a function

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Example **To delete the contents of function memory number 1**

AC OPTN F6 (▷) F5 (FMEM)
1 (Store) 1 EXE

```
== Function Memory ==
 f1:
```

• Executing the store operation while the display is blank deletes the function in the function memory you specify.

• To use stored functions

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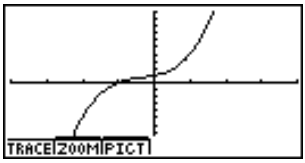
Example **To store $x^3 + 1$, $x^2 + x$ into function memory, and then graph: $y = x^3 + x^2 + x + 1$**

Use the following View Window settings.

Xmin = – 4, Xmax = 4, Xscale = 1
Ymin = –10, Ymax = 10, Yscale = 1

CTRL F3 (SET UP) ▼ F1 (Y=) ESC
AC X,θ,T ^ 3 + 1 OPTN F6 (▷) F5 (FMEM) 1 (Store) 1 EXE (stores $(x^3 + 1)$)
ESC AC X,θ,T x^2 + X,θ,T F5 (FMEM) 1 (Store) 2 EXE (stores $(x^2 + x)$)

ESC AC OPTN F6 (▷) F6 (▷) F2 (SKTCH) 1 (Cls) EXE
F2 (SKTCH) 4 (GRAPH) 1 (Y=)
OPTN F6 (▷) F5 (FMEM) 3 (fn) 1 +
F5 (FMEM) 3 (fn) 2 EXE



• For full details about graphing, see "5. Graphing".

You can also use → to store a function in function memory in a program.
In this case, you must enclose the function inside of double quotation marks.
The maximum size of the function you can store is 255 bytes.

```
"(A+B)(A-B)"→fn1
```

■ Answer Function

The Answer Function automatically stores the last result you calculated by pressing [EXE] (unless the [EXE] key operation results in an error). The result is stored in the answer memory.

• To use the contents of the answer memory in a calculation

● ● ● ● ●

Example **123 + 456 = 579**
789 – 579 = 210

[AC] [1] [2] [3] [+] [4] [5] [6] [EXE]
[7] [8] [9] [−] [SHIFT] [(−)] (Ans) [EXE]

■ Performing Continuous Calculations

Answer memory also lets you use the result of one calculation as one of the arguments in the next calculation.

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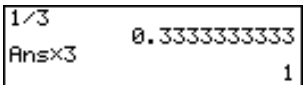
Example 1 **1 ÷ 3 =**
1 ÷ 3 × 3 =

[AC] [1] [÷] [3] [EXE]
(Continuing) [×] [3] [EXE]



Continuous calculations can also be used with Type A functions (x^2, x^{-1}, $x!$, page 2-1-3), +, –, ^(x^y), $\sqrt[x]{\ }$, ° ’ ”, etc.

The largest value that the answer memory can hold is 15 digits for the mantissa and 2 digits for the exponent.

Only numeric values and calculation results can be stored in answer memory.

Answer memory contents are not cleared when you press the [AC] key or when you switch power off.

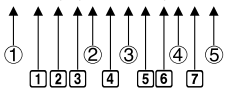
Answer memory contents are not changed by an operation that assigns values to value memory (such as: [5] [→] [ALPHA] [X,θ,T] (A) [EXE]).

■ Stacks

The unit employs memory blocks, called *stacks*, for storage of low priority values and commands. There is a 10-level *numeric value stack*, a 26-level *command stack*, and a 10-level *program subroutine stack*. An error occurs if you perform a calculation so complex that it exceeds the capacity of available numeric value stack or command stack space, or if execution of a program subroutine exceeds the capacity of the subroutine stack.

● ● ● ● ●

Example 2 × ((3 + 4 × (5 + 4) ÷ 3) ÷ 5) + 8 =



Numeric Value Stack

①	**2**
②	**3**
③	**4**
④	**5**
⑤	**4**
⋮	

Command Stack

1	×
2	(
3	(
4	+
5	×
6	(
7	+
⋮	

Calculations are performed according to the priority sequence. Once a calculation is executed, it is cleared from the stack.

Storing a complex number takes up two numeric value stack levels.

Storing a two-byte function takes up two command stack levels.

■ Using Multistatements

Multistatements are formed by connecting a number of individual statements for sequential execution. You can use multistatements in manual calculations and in programmed calculations. There are two different ways that you can use to connect statements to form multistatements.

• Colon (:)

Statements that are connected with colons are executed from left to right, without stopping.

• Display Result Command (◢)

When execution reaches the end of a statement followed by a display result command, execution stops and the result up to that point appears on the display. You can resume execution by pressing the [EXE] key.

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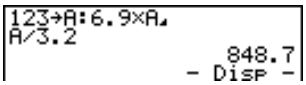
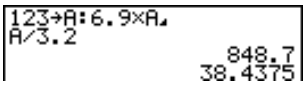
Example **6.9 × 123 = 848.7**
123 ÷ 3.2 = 38.4375

[AC] [1] [2] [3] [→] [ALPHA] [X,θ,T] (A)
[SHIFT] [VARS] (PRGM) [F6] (▷) [F6] (▷) [F3] (:) [6] [•] [9]
[×] [ALPHA] [X,θ,T] (A) [SHIFT] [VARS] (PRGM) [F4] (◢)
[ALPHA] [X,θ,T] (A) [÷] [3] [•] [2] [EXE]



[EXE]



The final result of a multistatement is always displayed, regardless of whether the calculation ends with a display result command.

You cannot construct a multistatement in which one statement directly uses the result of the previous statement.

Example : 123 × 456: × 5
Invalid

2-3 Specifying the Angle Unit and Display Format

Before performing a calculation for the first time, you should use the SET UP screen to specify the angle unit and display format.

■ Setting the Angle Unit

[SET UP]- [Angle]

1. On the Set Up screen, highlight "Angle".
2. Press the function key for the angle unit you want to specify, then press [ESC].
   - {**Deg**}/{**Rad**}/{**Gra**} ... {degrees}/{radians}{grads}
   - The relationship between degrees, grads, and radians is shown below.

     360° = 2π radians = 400 grads

     90° = π/2 radians = 100 grads

■ Setting the Display Format

[SET UP]- [Display]

1. On the Set Up screen, highlight "Display".
2. Press the function key for the item you want to set, then press [ESC].
   - {**Fix**}/{**Sci**}/{**Norm**}/{**Eng**} ... {fixed number of decimal places specification}/{number of significant digits specification}/{normal display}/{Engineering Mode}

• To specify the number of decimal places (Fix)

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Example To specify two decimal places

[F1](Fix) [2] [EXE]

Press the function key that corresponds to the number of decimal places you want to specify (n = 0 to 9).

Displayed values are rounded off to the number of decimal places you specify.

• To specify the number of significant digits (Sci)

● ● ● ● ●

Example **To specify three significant digits**

F2 (Sci) 3 EXE

Press the function key that corresponds to the number of significant digits you want to specify (n = 0 to 9).

• To specify the normal display (Norm 1/Norm 2)

Press F3 (Norm) to switch between Norm 1 and Norm 2.

Norm 1: 10^{-2} (0.01)>|*x*|, |*x*| ≧10^{10}

Norm 2: 10^{-9} (0.000000001)>|*x*|, |*x*| ≧10^{10}

AC 1 ÷ 2 0 0 EXE

(Norm 1)

(Norm 2)

• To specify the engineering notation display (Eng Mode)

Press F4 (Eng) to switch between engineering notation and standard notation. The indicator "/E" is on the display while engineering notation is in effect.

You can use the following symbols to convert values to engineering notation, such as 2,000 (= 2×10^3) → 2k.

E (Exa)	$\times 10^{18}$	m (milli)	$\times 10^{-3}$
P (Peta)	$\times 10^{15}$	μ (micro)	$\times 10^{-6}$
T (Tera)	$\times 10^{12}$	n (nano)	$\times 10^{-9}$
G (Giga)	$\times 10^{9}$	p (pico)	$\times 10^{-12}$
M (Mega)	$\times 10^{6}$	f (femto)	$\times 10^{-15}$
k (kilo)	$\times 10^{3}$		

Displayed values are rounded off to the number of significant digits you specify.
Specifying 0 makes the number of significant digits 10.
The engineering symbol that makes the mantissa a value from 1 to 1000 is automatically selected by the calculator when engineering notation is in effect.

2-4 Function Calculations

■ Function Menus

This calculator includes five function menus that give you access to scientific functions not printed on the key panel.

- The contents of the function menu differ according to the mode you entered from the Main Menu before you pressed the [OPTN] key. The following examples show function menus that appear in the RUN • MAT Mode.

● Numeric Calculations (NUM) [OPTN]-[NUM]

- {**Abs**} ... {select this item and input a value to obtain the absolute value of the value.}
- {**Int**}/{**Frac**} ... select the item and input a value to extract the {integer}/{fraction} part.
- {**Rnd**} ... {rounds off the value used for internal calculations to 10 significant digits (to match the value in the Answer Memory), or to the number of decimal places (Fix) and number of significant digits (Sci) specified by you.}
- {**Intg**} ... {select this item and input a value to obtain the largest integer that is not greater than the value.}
- {**E-SYM**} ... {engineering symbol}
  - {**m**}/{μ}/{**n**}/{**p**}/{**f**} ... {milli (10^{-3})}/{micro (10^{-6})}/{nano (10^{-9})}/{pico (10^{-12})}/{femto (10^{-15})}
  - {**k**}/{**M**}/{**G**}/{**T**}/{**P**}/{**E**} ... {kilo (10^{3})}/{mega (10^{6})}/{giga (10^{9})}/{tera (10^{12})}/{peta (10^{15})}/{exa (10^{18})}

● Probability/Distribution Calculations (PROB) [OPTN]-[PROB]

- {$x!$} ... {press after inputting a value to obtain the factorial of the value.}
- {n**Pr**}/{n**Cr**} ... {permutation}/{combination}
- {**Ran#**}... {pseudo random number generation (0 to 1)}
- {**P**()}/{**Q**()}/{**R**()} ... normal probability {P(t)}/{Q(t)}/{R(t)}
- {t()} ... {value of normalized variate $t(x)$}

• Hyperbolic Calculations (HYP) [OPTN]-[HYP]

- {**sinh**}/{**cosh**}/{**tanh**} ... hyperbolic {sine}/{cosine}/{tangent}
- {**sinh**$^{-1}$}/{**cosh**$^{-1}$}/{**tanh**$^{-1}$} ... inverse hyperbolic {sine}/{cosine}/{tangent}

• Angle Units, Coordinate Conversion, Sexagesimal Operations (ANGL)

[OPTN]-[ANGL]

- {°}/{**r**}/{**g**} ... {degrees}/{radians}/{grads} for a specific input value
- {° ’ ”} ... {specifies degrees (hours), minutes, seconds when inputting a degrees/minutes/seconds value}
- {►**DMS**} ... {converts decimal value to sexagesimal value}
- {**Pol(**}/{**Rec(**} ... {rectangular-to-polar}/{polar-to-rectangular} coordinate conversion

• Instant Functions

- {◿° ’ ”} ... {converts decimal value to degrees/minutes/seconds value}
- {**ENG**}/{◿**ENG**} ... shifts the decimal place of the displayed value three digits to the {left}/{right} and {decreases}/{increases} the exponent by three. When you are using engineering notation, the engineering symbol is also changed accordingly.
- The {◿° ’ ” }, {ENG} and {◿ENG} menu operations are available only when there is a calculation result on the display.

■ Angle Units

To change the angle unit of an input value, first press [OPTN] [F3](ANGL). On the pull-up menu that appears, select “o”, “r”, or “g”.

- Be sure to specify Comp for Mode in the SET UP screen.

Example	Operation
To convert 4.25 rad to degrees: 243.5070629	[CTRL] [F3](SET UP)▼▼▼▼ [F1](Deg) [ESC] **4.25** [OPTN] [F6](▷) [F3](ANGL) [2](r) [EXE]
47.3° + 82.5rad = 4774.20181°	**47.3** [+] **82.5** [OPTN] [F6](▷) [F3](ANGL) [2](r) [EXE]

Once you specify an angle unit, it remains in effect until you specify a different one.

The specification is retained even if you turn power off.

■ Trigonometric and Inverse Trigonometric Functions

- Be sure to set the angle unit before performing trigonometric function and inverse trigonometric function calculations.

  ($90° = \frac{\pi}{2}$ radians = 100 grads)

- Be sure to specify Comp for Mode in the SET UP screen.

Example	Operation
$\sin 63° = 0.8910065242$	[CTRL] [F3] (SET UP) ▼ ▼ ▼ ▼ [F1] (Deg) [ESC] [sin] **63** [EXE]
$\cos(\frac{\pi}{3}\text{ rad}) = 0.5$	[CTRL] [F3] (SET UP) ▼ ▼ ▼ ▼ [F2] (Rad) [ESC] [cos] [(] [SHIFT] [EXP] (π) [÷] [3] [)] [EXE]
$\tan(-35\text{gra}) = -0.6128007881$	[CTRL] [F3] (SET UP) ▼ ▼ ▼ ▼ [F3] (Gra) [ESC] [tan] [(−)] **35** [EXE]
$2 \cdot \sin 45° \times \cos 65° = 0.5976724775$	[CTRL] [F3] (SET UP) ▼ ▼ ▼ ▼ [F1] (Deg) [ESC] **2** [×] [sin] **45** [×] [cos] **65** [EXE] *1
$\text{cosec}\,30° = \frac{1}{\sin 30°} = 2$	**1** [÷] [sin] **30** [EXE]
$\sin^{-1}0.5 = 30°$ (x when $\sin x = 0.5$)	[SHIFT] [sin] ($\sin^{-1}$) **0.5** *2 [EXE]

*1 [×] can be omitted.

*2 Input of leading zero is not necessary.

■ Logarithmic and Exponential Functions

• Be sure to specify Comp for Mode in the SET UP screen.

Example	Operation
log 1.23 ($\log_{10}1.23$) = $8.990511144 \times 10^{-2}$	[log] **1.23** [EXE]
ln 90 ($\log_e 90$) = 4.49980967	[ln] **90** [EXE]
$10^{1.23}$ = 16.98243652 (To obtain the antilogarithm of common logarithm 1.23)	[SHIFT] [log] (10^x) **1.23** [EXE]
$e^{4.5}$ = 90.0171313 (To obtain the antilogarithm of natural logarithm 4.5)	[SHIFT] [ln] (e^x) **4.5** [EXE]
$(-3)^4 = (-3) \times (-3) \times (-3) \times (-3) = 81$	[(] [(−)] **3** [)] [^] **4** [EXE]
$-3^4 = -(3 \times 3 \times 3 \times 3) = -81$	[(−)] **3** [^] **4** [EXE]
$\sqrt[7]{123}$ ($= 123^{\frac{1}{7}}$) = 1.988647795	**7** [SHIFT] [^] ($\sqrt[x]{\ }$) **123** [EXE]
$2 + 3 \times \sqrt[3]{64} - 4 = 10$	**2** [+] **3** [×] **3** [SHIFT] [^] ($\sqrt[x]{\ }$) **64** [−] **4** [EXE] *1

*1 ^ (x^y) and $\sqrt[x]{\ }$ take precedence over multiplication and division.

■ Hyperbolic and Inverse Hyperbolic Functions

• Be sure to specify Comp for Mode in the SET UP screen.

Example	Operation
sinh 3.6 = 18.28545536	OPTN F6(▷) F2(HYP) 1(sinh)**3.6** EXE
cosh 1.5 – sinh 1.5 = 0.2231301601 $= e^{-1.5}$ (Display: –1.5) (Proof of cosh $x \pm$ sinh $x = e^{\pm x}$)	OPTN F6(▷) F2(HYP) 2(cosh)**1.5** − F2(HYP) 1(sinh)**1.5** EXE In SHIFT (↔)(Ans) EXE
$\cosh^{-1}\left(\frac{20}{15}\right) = 0.7953654612$	OPTN F6(▷) F2(HYP) 5(cosh^{-1})(**20** ÷ **15**) EXE
Determine the value of x when tanh 4 x = 0.88 $x = \frac{\tanh^{-1} 0.88}{4}$ = 0.3439419141	OPTN F6(▷) F2(HYP) 6(tanh^{-1})**0.88** ÷ **4** EXE

■ Other Functions

• Be sure to specify Comp for Mode in the SET UP screen.

Example	Operation
$\sqrt{2}+\sqrt{5}=3.65028154$	[SHIFT] [x^3] ($\sqrt{\ }$) **2** [+] [SHIFT] [x^2] ($\sqrt{\ }$) **5** [EXE]
$\sqrt{(3+i)}=$ 1.755317302 +0.2848487846i	[SHIFT] [x^3] ($\sqrt{\ }$) [(] **3** [+] [SHIFT] **0** (i) [)] [EXE]
$(-3)^2=(-3)\times(-3)=9$	[(] [(–)] **3** [)] [x^3] [EXE]
$-3^2=-(3\times3)=-9$	[(–)] **3** [x^2] [EXE]
$\dfrac{1}{\frac{1}{3}-\frac{1}{4}}=12$	[(] **3** [SHIFT] [)] (x^{-1}) [−] **4** [SHIFT] [)] (x^{-1}) [)] [SHIFT] [)] (x^{-1}) [EXE]
8! (= $1\times2\times3\times....\times8$) = 40320	**8** [OPTN] [F6] (▷) [F1] (PROB) **1** ($x!$) [EXE]
$\sqrt[3]{36\times42\times49}=42$	[SHIFT] [(] ($\sqrt[3]{\ }$) [(] **36** [×] **42** [×] **49** [)] [EXE]
What is the absolute value of the common logarithm of $\frac{3}{4}$? $\left\|\log\frac{3}{4}\right\|=0.1249387366$	[OPTN] [F5] (NUM) **1** (Abs) [log] [(] **3** [÷] **4** [)] [EXE]
What is the integer part of – 3.5? – 3	[OPTN] [F5] (NUM) **2** (Int) [(–)] **3.5** [EXE]
What is the decimal part of – 3.5? – 0.5	[OPTN] [F5] (NUM) **3** (Frac) [(–)] **3.5** [EXE]
What is the nearest integer not exceeding – 3.5? – 4	[OPTN] [F5] (NUM) **5** (Intg) [(–)] **3.5** [EXE]

■ Random Number Generation (Ran#)

This function generates a 10-digit truly random or sequentially random number that is greater than zero and less than 1.

- A truly random number is generated if you do not specify anything for the argument.

Example	Operation
Ran # (Generates a random number.)	OPTN F6 (▷) F1 (PROB) 4 (Ran#) EXE
(Each press of EXE generates a new random number.)	EXE EXE

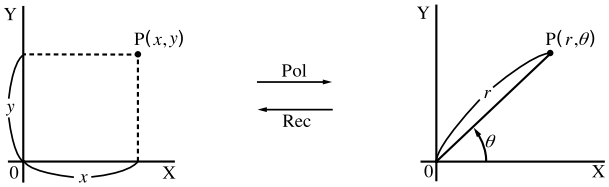
- Specifying an argument from 1 to 9 generates random numbers based on that sequence.
- Specifying an argument of 0 initializes the sequence.*1

Example	Operation
Ran# 1 (Generates the first random number in sequence 1.) (Generates the second random number in sequence 1.)	F1 (PROB) 4 (Ran#) 1 EXE EXE
Ran# 0 (Initializes the sequence.) Ran# 1 (Generates the first random number in sequence 1.)	F1 (PROB) 4 (Ran#) 0 EXE F1 (PROB) 4 (Ran#) 1 EXE

*1 Changing to a different sequence or generating a totally random number (without an argument) initializes the sequence.

■ Coordinate Conversion

• Rectangular Coordinates **• Polar Coordinates**



- With polar coordinates, θ can be calculated and displayed within a range of $-180° < \theta \leqq 180°$ (radians and grads have same range).
- Be sure to specify Comp for Mode in the SET UP screen.

Example	Operation
Calculate r and $\theta°$ when x = 14 and y = 20.7 1 [24.989] → 24.98979792 (r) 2 [55.928] → 55.92839019 (θ)	CTRL F3 (SET UP) ▼ ▼ ▼ ▼ F1 (Deg) ESC OPTN F6 (▷) F3 (ANGL) 6 (Pol() **14** , **20.7**) EXE
Calculate x and y when r = 25 and θ = 56° 1 [13.979] → 13.97982259 (x) 2 [20.725] → 20.72593931 (y)	CTRL F3 (SET UP) ▼ ▼ ▼ ▼ F1 (Deg) ESC OPTN F6 (▷) F3 (ANGL) 7 (Rec() **25** , **56**) EXE

■ Permutation and Combination

• Permutation

$$ {}_nPr = \frac{n!}{(n-r)!} $$

• Combination

$$ {}_nCr = \frac{n!}{r!\,(n-r)!} $$

• Be sure to specify Comp for Mode in the SET UP screen.

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Example **To calculate the possible number of different arrangements using 4 items selected from among 10 items**

Formula	Operation
${}_{10}P_4 = 5040$	**10** [OPTN] [F6] (▷) [F1] (PROB) [2] ($_nP_r$) **4** [EXE]

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Example **To calculate the possible number of different combinations of 4 items that can be selected from among 10 items**

Formula	Operation
${}_{10}C_4 = 210$	**10** [OPTN] [F6] (▷) [F1] (PROB) [3] ($_nC_r$) **4** [EXE]

■ Fractions

- Fractional values are displayed with the integer first, followed by the numerator and then the denominator.
- Be sure to specify Comp for Mode in the SET UP screen.

Example	Operation
$\frac{2}{5} + 3\frac{1}{4} = 3\frac{13}{20}$ (Display: 3⌟13⌟20) $= 3.65$	**2** [a b/c] **5** [+] **3** [a b/c] **1** [a b/c] **4** [EXE] [a b/c] (Conversion to decimal) [a b/c] (Conversion to fraction)
$\frac{1}{2578} + \frac{1}{4572} = 6.066202547 \times 10^{-4}$ (Display: $6.066202547_{E}-04$*1) (Norm 1 display format)	**1** [a b/c] **2578** [+] **1** [a b/c] **4572** [EXE]
$\frac{1}{2} \times 0.5 = 0.25$*2 $= \frac{1}{4}$	**1** [a b/c] **2** [×] **.5** [EXE] [a b/c]
$1.5 + 2.3i = 1\frac{1}{2} + 2\frac{3}{10}i$ (Display: 1⌟1⌟2 +2⌟3⌟10**i**)	**1.5** [+] **2.3** [SHIFT] [0] (*i*) [EXE] [a b/c] [a b/c] *3
$\frac{1}{\frac{1}{3}+\frac{1}{4}} = 1\frac{5}{7}$ (Display: 1⌟5⌟7)	**1** [a b/c] [(] **1** [a b/c] **3** [+] **1** [a b/c] **4** [)] [EXE] *4

*1 When the total number of characters, including integer, numerator, denominator and delimiter marks exceeds 10, the input fraction is automatically displayed in decimal format.

*2 Calculations containing both fractions and decimals are calculated in decimal format.

*3 Pressing [a b/c] once when converting the decimal part of a complex number to a fraction first displays the real part and imaginary part on separate lines.

*4 You can include fractions within the numerator or denominator of a fraction by putting the numerator or denominator in parentheses.

■ Engineering Notation Calculations

Input engineering symbols using the engineering notation menu.

• Be sure to specify Comp for Mode in the SET UP screen.

Example	Operation
	[CTRL] [F3] (SET UP) ▼ ▼ ▼ ▼ ▼ ▼ ▼ ▼ ▼ ▼ ▼ [F4] (Eng) [ESC]
999k (kilo) + 25k (kilo) = 1.024M (mega)	**999** [OPTN] [F5] (NUM) [6] (E-SYM) [6] (k) [+] **25** [F5] (NUM) [6] (E-SYM) [6] (k) [EXE]
9 ÷ 10 = 0.9 = 900m (milli)	**9** [÷] **10** [EXE]
= 0.9	[OPTN] [F6] (▷) [F6] (▷) [F6] (▷) [F3] (↙ENG)*1
= 0.0009k (kilo)	[F3] (↙ENG)*1
= 0.9	[F2] (ENG)*2
= 900m	[F2] (ENG)*2

*1 Converts the displayed value to the next higher engineering unit, by shifting the decimal point three places to the right.

*2 Converts the displayed value to the next lower engineering unit, by shifting the decimal point three places to the left.

2-5 Numerical Calculations

The following describes the items that are available in the menus you use when performing differential/ quadratic differential, integration, Σ, maximum/minimum value, and Solve calculations.

When the option menu is on the display, press F4(CALC) to display the function analysis menu. The items of this menu are used when performing specific types of calculations.

- {d/dx}/{d^2/dx^2}/{$\int dx$}/{Σ}/{**FMin**}/{**FMax**}/{**Solve**} ... {differential}/{quadratic differential}/{integration}/{Σ (sigma)}/{minimum value}/{maximum value}/{solve} calculations

Solve calculations

The following is the syntax for using the Solve function in a program.

Solve($f(x)$, n, a, b) (a: lower limit, b: upper limit, n: initial estimated value)

- There are two different input methods that can be used for Solve calculations: direct assignment and variable table input.

  With the direct assignment method (the one described here), you assign values directly to variables. This type of input is identical to that used with the Solve command used in the PRGM Mode.

  Variable table input is used with the Solve function in the EQUA Mode. This input method is recommend for most normal Solve function input.

  An Error (Iteration ERROR) occurs when there is no convergence of the solution.

■ Differential Calculations

[OPTN]-[CALC]-[d/dx]

To perform differential calculations, first display the function analysis menu, and then input the values shown in the formula below.

[OPTN] [F4] (CALC) [1] (d/dx) $f(x)$ [,] a [,] tol [)]

(a: point for which you want to determine the derivative, tol: tolerance)

$$d/dx\,(f(x), a) \Rightarrow \frac{d}{dx} f(a)$$

The differentiation for this type of calculation is defined as:

$$f'(a) = \lim_{\Delta x \to 0} \frac{f(a + \Delta x) - f(a)}{\Delta x}$$

In this definition, *infinitesimal* is replaced by a *sufficiently small* Δx, with the value in the neighborhood of $f'(a)$ calculated as:

$$f'(a) \fallingdotseq \frac{f(a + \Delta x) - f(a)}{\Delta x}$$

In order to provide the best precision possible, this unit employs central difference to perform differential calculations.

Using Differential Calculation in a Graph Function

- Omitting the tolerance (tol) value when using the differential command inside of a graph function simplifies the calculation for drawing the graph. In such a case, precision is sacrificed for the sake of faster drawing. The tolerance value is specified, the graph is drawn with the same precision obtained when you normally perform a differential calculation.
- You can also omit input of the derivative point by using the following format for the differential graph: Y2=d/dx(Y1). In this case, the value of the X variable is used as the derivative point.

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Example **To determine the derivative at point x = 3 for the function $y = x^3 + 4x^2 + x - 6$, with a tolerance of "*tol*" = 1E – 5**

Input the function $f(x)$.

AC OPTN F4 (CALC) 1 (d/dx) X,θ,T ^ 3 + 4 X,θ,T x^2 + X,θ,T − 6)

Input point $x = a$ for which you want to determine the derivative.

3)

Input the tolerance value.

1 EXP (−) 5)

EXE

```
d/dx(X^3+4X²+X-6,3,1E
-5)
                    52
```

In the function $f(x)$, only X can be used as a variable in expressions. Other variables (A through Z, r, θ) are treated as constants, and the value currently assigned to that variable is applied during the calculation.
Input of the tolerance (*tol*) value and the closing parenthesis can be omitted. If you omit tolerance (*tol*) value, the calculator automatically uses a value for *tol* as 1E-10.
Specify tolerance (*tol*) value of 1E-14 or less. An error (Iteration ERROR) occurs whenever no solution that satisfies the tolerance value can be obtained.
Discontinuous points or sections with drastic fluctuation can adversely affect precision or even cause an error.

• Applications of Differential Calculations

• Differentials can be added, subtracted, multiplied or divided with each other.

$$\frac{d}{dx} f(a) = f'(a),\ \frac{d}{dx} g(a) = g'(a)$$

Therefore:

$$f'(a) + g'(a),\ f'(a) \times g'(a), \text{ etc.}$$

• Differential results can be used in addition, subtraction, multiplication, and division, and in functions.

$$2 \times f'(a), \log(f'(a)), \text{ etc.}$$

• Functions can be used in any of the terms ($f(x)$, a, tol) of a differential.

$$\frac{d}{dx}(\sin x + \cos x, \sin 0.5, 1\text{E} - 8), \text{ etc.}$$

You cannot use a differential, quadratic differential, integration, Σ, maximum/minimum value or solve calculation expression inside a differential calculation term.

Pressing [AC] during calculation of a differential (while the cursor is not shown on the display) interrupts the calculation.

Always use radians (Rad Mode) as the angle unit when performing trigonometric differentials.

■ Quadratic Differential Calculations

[OPTN]-[CALC]-[d^2/dx^2]

After displaying the function analysis menu, you can input quadratic differentials using either of the two following formats.

[OPTN] [F4] (CALC) [2] (d^2/dx^2) $f(x)$ [,] a [,] tol [)]

(a: differential coefficient point, tol: tolerance)

$$\frac{d^2}{dx^2}(f(x), a) \Rightarrow \frac{d^2}{dx^2} f(a)$$

Quadratic differential calculations produce an approximate differential value using the following second order differential formula, which is based on Newton's polynomial interpretation.

$$f''(a) = \frac{2f(a+3h) - 27f(a+2h) + 270f(a+h) - 490f(a) + 270f(a-h) - 27f(a-2h) + 2f(a-3h)}{180h^2}$$

In this expression, values for "sufficiently small increments of h" are used to obtain a value that approximates $f''(a)$.

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Example **To determine the quadratic differential coefficient at the point where $x = 3$ for the function $y = x^3 + 4x^2 + x - 6$**
Here we will use a tolerance $tol = 1\text{E} - 5$

Input the function $f(x)$.

[AC] [OPTN] [F4] (CALC) [2] (d^2/dx^2) [X,θ,T] [^] [3] [+]
[4] [X,θ,T] [x^2] [+] [X,θ,T] [−] [6] [,]

Input 3 as point a, which is the differential coefficient point.

[3] [,]

Input the tolerance value.

[1] [EXP] [(−)] [5] [)]
[EXE]

```
d²/dx²(X^3+4X²+X-6,3,
1E-5)
                    26
```

In the function $f(x)$, only X can be used as a variable in expressions. Other variables (A through Z, r, θ) are treated as constants, and the value currently assigned to that variable is applied during the calculation.

Input of the tolerance (tol) value and the closing parenthesis can be omitted.
Discontinuous points or sections with drastic fluctuation can adversely affect precision or even cause an error.

• Quadratic Differential Applications

- Arithmetic operations can be performed using two quadratic differentials.

$$\frac{d^2}{dx^2} f(a) = f''(a),\ \frac{d^2}{dx^2} g(a) = g''(a)$$

Therefore:

$$f''(a) + g''(a),\ f''(a) \times g''(a), \text{ etc.}$$

- The result of a quadratic differential calculation can be used in a subsequent arithmetic or function calculation.

$$2 \times f''(a),\ \log(f''(a)), \text{ etc.}$$

- Functions can be used within the terms ($f(x)$, a, tol) of a quadratic differential expression.

$$\frac{d^2}{dx^2}(\sin x + \cos x,\ \sin 0.5,\ 1\text{E}-8), \text{ etc.}$$

You cannot use a differential, quadratic differential, integration, Σ, maximum/minimum value or Solve calculation expression inside of a quadratic differential calculation term.
Specify tolerance (tol) value of 1E-14 or less. An error (Iteration ERROR) occurs whenever no solution that satisfies the tolerance value can be obtained.
You can interrupt an ongoing quadratic differential calculation by pressing the AC key.
Always use radians (Rad Mode) as the angle unit when performing trigonometric quadratic differentials.
Using Quadratic Differential Calculation in a Graph Function (see page 2-5-2)

■ Integration Calculations

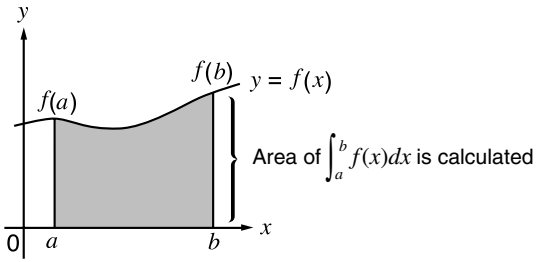
[OPTN]-[CALC]-[∫dx]

To perform integration calculations, first display the function analysis menu and then input the values in the formula shown below.

OPTN F4 (CALC) 3 (∫dx) $f(x)$, a , b , tol)

(a: start point, b: end point, tol: tolerance)

$$\int(f(x), a, b, tol) \Rightarrow \int_a^b f(x)dx$$



As shown in the illustration above, integration calculations are performed by calculating integral values from a through b for the function $y = f(x)$ where $a \leqq x \leqq b$, and $f(x) \geqq 0$. This in effect calculates the surface area of the shaded area in the illustration.

If $f(x) < 0$ where $a \leqq x \leqq b$, the surface area calculation produces negative values (surface area × – 1).

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Example **To perform the integration calculation for the function shown below, with a tolerance of "*tol*" = 1E - 4**

$$\int_1^5 (2x^2 + 3x + 4)\,dx$$

Input the function $f(x)$.

AC OPTN F4 (CALC) 3 ($\int dx$) 2 X,θ,T x^2 + 3 X,θ,T + 4)

Input the start point and end point.

1 , 5)

Input the tolerance value.

1 EXP (−) 4)

EXE

```
∫(2X²+3X+4,1,5,1E-4)
                134.6666667
```

• Application of Integration Calculation

- Integrals can be used in addition, subtraction, multiplication or division.

$$\int_a^b f(x)\,dx + \int_c^d g(x)\,dx, \text{ etc.}$$

- Integration results can be used in addition, subtraction, multiplication or division, in functions.

$$2 \times \int_a^b f(x)\,dx, \text{ etc. } \log\left(\int_a^b f(x)\,dx\right), \text{ etc.}$$

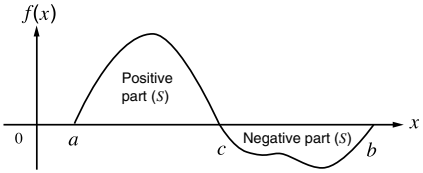
- Functions can be used in any of the terms ($f(x)$, a, b, tol) of an integral.

$$\int_{\sin 0.5}^{\cos 0.5} (\sin x + \cos x)\,dx = \int(\sin x + \cos x, \sin 0.5, \cos 0.5, 1\text{E} - 4)$$

In the function $f(x)$, only X can be used as a variable in expressions. Other variables (A through Z, r, θ) are treated as constants, and the value currently assigned to that variable is applied during the calculation.
Input of "*tol*" and closing parenthesis can be omitted. If you omit "*tol*," the calculator automatically uses a default value of 1E-5.
Integration calculations can take a long time to complete.
You cannot use a differential, quadratic differential, integration, Σ, maximum/minimum value or Solve calculation expression inside of an integration calculation term.

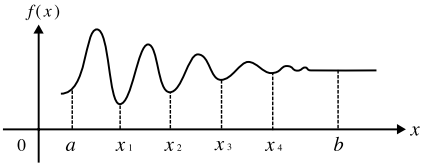
Note the following points to ensure correct integration values.

(1) When cyclical functions for integration values become positive or negative for different divisions, perform the calculation for single cycles, or divide between negative and positive, and then add the results together.



$$\int_a^b f(x)dx = \underbrace{\int_a^c f(x)dx}_{\text{Positive part } (S)} + \underbrace{(-\int_c^b f(x)dx)}_{\text{Negative part } (S)}$$

(2) When minute fluctuations in integration divisions produce large fluctuations in integration values, calculate the integration divisions separately (divide the large fluctuation areas into smaller divisions), and then add the results together.



$$\int_a^b f(x)dx = \int_a^{x_1} f(x)dx + \int_{x_1}^{x_2} f(x)dx + \ldots\ldots + \int_{x_4}^b f(x)dx$$

Pressing [AC] during calculation of an integral (while the cursor is not shown on the display) interrupts the calculation.

Always use radians (Rad Mode) as the angle unit when performing trigonometric integrations.

An error (Iteration ERROR) occurs whenever no solution that satisfies the tolerance value can be obtained.

■ Σ Calculations

[OPTN]-[CALC]-[Σ]

To perform Σ calculations, first display the function analysis menu, and then input the values shown in the formula below.

[OPTN] [F4] (CALC) [4] (Σ) a_k [,] k [,] α [,] β [,] n [)]

$$\sum(a_k, k, \alpha, \beta, n) = \sum_{k=\alpha}^{\beta} a_k = a_\alpha + a_{\alpha+1} + \ldots\ldots + a_\beta$$

(n: distance between partitions)

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Example **To calculate the following:**

$$\sum_{k=2}^{6} (k^2 - 3k + 5)$$

Use n = 1 as the distance between partitions.

[AC] [OPTN] [F4] (CALC) [4] (Σ) [ALPHA] [,] (K) [x^2]
[−] [3] [ALPHA] [,] (K) [+] [5] [,]
[ALPHA] [,] (K) [,] [2] [,] [6] [,] [1] [)] [EXE]

```
Σ(K²-3K+5,K,2,6,1)
                  55
```

You can use only one variable in the function for input sequence a_k.
Input integers only for the initial term (α) of sequence a_k and last term (β) of sequence a_k .
Input of n and the closing parentheses can be omitted. If you omit n, the calculator automatically uses n = 1.

• Σ Calculation Applications

• Arithmetic operations using Σ calculation expressions

Expressions: $S_n = \sum_{k=1}^{n} a_k$, $T_n = \sum_{k=1}^{n} b_k$

Possible operations: $S_n + T_n$, $S_n - T_n$, etc.

• Arithmetic and function operations using Σ calculation results

$2 \times S_n$, $\log(S_n)$, etc.

• Function operations using Σ calculation terms (a_k, k)

$\Sigma(\sin k, k, 1, 5)$, etc.

You cannot use a differential, quadratic differential, integration, Σ, maximum/minimum value or Solve calculation expression inside of a Σ calculation term.

Make sure that the value used as the final term β is greater than the value used as the initial term α. Otherwise, an error will occur.

To interrupt an ongoing Σ calculation (indicated when the cursor is not on the display), press the AC key.

■ Maximum/Minimum Value Calculations [OPTN]-[CALC]-[FMin]/[FMax]

After displaying the function analysis menu, you can input maximum/minimum calculations using the formats below, and solve for the maximum and minimum of a function within interval $a \leqq x \leqq b$. (a: start point of interval, b: end point of interval, n: precision (n = 1 to 9))

●Minimum Value

OPTN F4 (CALC) 5 (FMin) $f(x)$, a , b , n)

●Maximum Value

OPTN F4 (CALC) 6 (FMax) $f(x)$, a , b , n)

● ● ● ● ●

Example 1 **To determine the minimum value for the interval defined by start point a = 0 and end point b = 3, with a precision of n = 6 for the function $y = x^2 - 4x + 9$**

Input $f(x)$.

AC OPTN F4 (CALC) 5 (FMin) X,θ,T x^2 − 4 X,θ,T + 9 ,

Input the interval a = 0, b = 3.

0 , 3 ,

Input the precision n = 6.

6)

EXE

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Example 2 **To determine the maximum value for the interval defined by start point a = 0 and end point b = 3, with a precision of n = 6 for the function $y = -x^2 + 2x + 2$**

Input $f(x)$.

AC OPTN F4 (CALC) 6 (FMax) (−) X,θ,T x^2 + 2 X,θ,T + 2)

Input the interval a = 0, b = 3.

0 , 3)

Input the precision n = 6.

6)

EXE

In the function $f(x)$, only X can be used as a variable in expressions. Other variables (A through Z, r, θ) are treated as constants, and the value currently assigned to that variable is applied during the calculation.
Input of n and the closing parenthesis can be omitted.
Discontinuous points or sections with drastic fluctuation can adversely affect precision or even cause an error.
You cannot use a differential, quadratic differential, integration, Σ, maximum/minimum value or Solve calculation expression inside of a maximum/minimum calculation term.
Inputting a larger value for n increases the precision of the calculation, but it also increases the amount of time required to perform the calculation.
The value you input for the end point of the interval (b) must be greater than the value you input for the start point (a). Otherwise an error occurs.
You can interrupt an ongoing maximum/minimum calculation by pressing the AC key.
You can input an integer in the range of 1 to 9 for the value of n. Using any value outside this range causes an error.

2-6 Complex Number Calculations

You can perform addition, subtraction, multiplication, division, parentheses calculations, function calculations, and memory calculations with complex numbers just as you do with the manual calculations described on pages 2-1-1 and 2-4-6.

You can select the complex number calculation mode by changing the Complex Mode item on the SET UP screen to one of the following settings.

- {**Real**} ... Calculation in the real number range only*1
- {***a+bi***} ... Performs complex number calculation and displays results in rectangular form
- {***re^θi***} ... Performs complex number calculation and displays results in polar form*2

Press OPTN F3 (CPLX) to display the complex calculation number menu, which contains the following items.

- {**Abs**}/{**Arg**} ... obtains {absolute value}/{argument}
- {**Conjg**} ... {obtains conjugate}
- {**ReP**}/{**ImP**} ... {real}/{imaginary} part extraction
- {►***re^θi***}/{►***a+bi***} ... converts the result to {polar}/{linear}

*1 When there is an imaginary number in the argument, however, complex number calculation is performed and the result is displayed using rectangular form.

Examples:
ln 2*i* = 0.6931471806 + 1.570796327*i*
ln 2*i* + ln (- 2) = (Non-Real ERROR)

*2 The display range of θ depends on the angle unit set for the Angle item on the SET UP screen.

- Deg ... $-180 < \theta \leqq 180$
- Rad ... $-\pi < \theta \leqq \pi$
- Gra ... $-200 < \theta \leqq 200$

Solutions obtained by the Real and $a+bi$ / $re^{\wedge}\theta i$ modes are different for power root (x^y) calculations when $x < 0$ and $y = m/n$ when n is an odd number.

Example:
$\sqrt[3]{(-8)}$ = – 2 (Real)
= 1 + 1.732050808*i*(*a+bi* / *re^θi*)

■ Absolute Value and Argument

[OPTN]-[CPLX]-[Abs]/[Arg]

The unit regards a complex number in the form $a + bi$ as a coordinate on a Gaussian plane, and calculates absolute value $|Z|$ and argument (arg).

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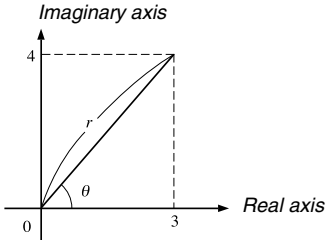
Example **To calculate absolute value (r) and argument (θ) for the complex number 3 + 4*i*, with the angle unit set for degrees**



AC OPTN F3 (CPLX) 1 (Abs)
(3 + 4 SHIFT 0 (*i*)) EXE

(Calculation of absolute value)

```
Abs (3+4i)
                5
```

AC OPTN F3 (CPLX) 2 (Arg)
(3 + 4 SHIFT 0 (*i*)) EXE

(Calculation of argument)

```
Arg (3+4i)
      53.13010235
```

The result of the argument calculation differs in accordance with the current angle unit setting (degrees, radians, grads).

■ Conjugate Complex Numbers

[OPTN]-[CPLX]-[Conjg]

A complex number of the form $a + bi$ becomes a conjugate complex number of the form $a - bi$.

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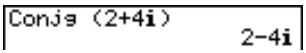
Example **To calculate the conjugate complex number for the complex number 2 + 4*i***

AC OPTN F3 (CPLX) 3 (Conjg)
(2 + 4 SHIFT 0 (*i*)) EXE



■ Extraction of Real and Imaginary Parts

[OPTN]-[CPLX]-[ReP]/[ImP]

Use the following procedure to extract the real part a and the imaginary part b from a complex number of the form $a + bi$.

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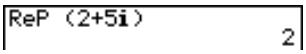
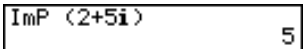
Example **To extract the real and imaginary parts of the complex number 2 + 5*i***

AC OPTN F3 (CPLX) 4 (ReP)
(2 + 5 SHIFT 0 (*i*)) EXE
(Real part extraction)



AC OPTN F3 (CPLX) 5 (ImP)
(2 + 5 SHIFT 0 (*i*)) EXE
(Imaginary part extraction)



The input/output range of complex numbers is normally 10 digits for the mantissa and two digits for the exponent.
When a complex number has more than 21 digits, the real part and imaginary part are displayed on separate lines.
When either the real part or imaginary part of a complex number equals zero, that part is not displayed in rectangular form.
18 bytes of memory are used whenever you assign a complex number to a variable.
The following functions can be used with complex numbers.
$\sqrt{\ }$, x^2, x^{-1}, $\wedge(x^y)$, $\sqrt[3]{\ }$, $\sqrt[x]{\ }$, ln, log, 10^x, e^x, sin, cos, tan, $\sin^{-1}$, $\cos^{-1}$, $\tan^{-1}$, sinh, cosh, tanh, $\sinh^{-1}$, $\cosh^{-1}$, $\tanh^{-1}$
Int, Frac, Rnd, Intg, Fix, Sci, ENG, ←ENG, ° ' ", ←° ' ", $a\ ^b/_c$, d/c

■ Polar Form and Rectangular Transformation

[OPTN]-[CPLX]-[►$re^{\wedge}\theta i$]

Use the following procedure to transform a complex number displayed in rectangular form to polar form, and vice versa.

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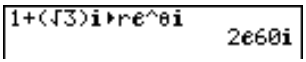
Example **To transform the rectangular form of complex number 1 + $\sqrt{3}i$ to its polar form**

AC 1 + (SHIFT x^2 (√) 3) SHIFT 0 (i)
OPTN F3 (CPLX) 6 (►$re^{\wedge}\theta i$) EXE



2-7 Binary, Octal, Decimal, and Hexadecimal Calculations with Integers

You can use the **RUN • MAT Mode** and binary, octal, decimal, and hexadecimal settings to perform calculations that involve binary, octal, decimal and hexadecimal values. You can also convert between number systems and perform bitwise operations.

- You cannot use scientific functions in binary, octal, decimal, and hexadecimal calculations.
- You can use only integers in binary, octal, decimal, and hexadecimal calculations, which means that fractional values are not allowed. If you input a value that includes a decimal part, the unit automatically cuts off the decimal part.
- If you attempt to enter a value that is invalid for the number system (binary, octal, decimal, hexadecimal) you are using, the calculator displays an error message. The following shows the numerals that can be used in each number system.

  Binary: 0, 1

  Octal: 0, 1, 2, 3, 4, 5, 6, 7

  Decimal: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9

  Hexadecimal: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F

- Negative binary, octal, and hexadecimal values are produced using the two's complement of the original value.
- The following are the display capacities for each of the number systems.

Number System	Display Capacity
Binary	16 digits
Octal	11 digits
Decimal	10 digits
Hexadecimal	8 digits

The alphabetic characters used in the hexadecimal number appear differently on the display to distinguish them from text characters.

Normal Text	A	B	C	D	E	F
Hexadecimal Values	A	B	C	D	E	F
Keys	X,θ,T	log	ln	sin	cos	tan

• The following are the calculation ranges for each of the number systems.

Binary Values

Positive: $0 \leqq x \leqq 111111111111111$

Negative: $1000000000000000 \leqq x \leqq 1111111111111111$

Octal Values

Positive: $0 \leqq x \leqq 17777777777$

Negative: $20000000000 \leqq x \leqq 37777777777$

Decimal Values

Positive: $0 \leqq x \leqq 2147483647$

Negative: $-2147483648 \leqq x \leqq -1$

Hexadecimal Values

Positive: $0 \leqq x \leqq 7FFFFFFF$

Negative: $80000000 \leqq x \leqq FFFFFFFF$

• To perform a binary, octal, decimal, or hexadecimal calculation

[SET UP]- [Mode] -[Dec]/[Hex]/[Bin]/[Oct]

1. In the main menu, select **RUN • MAT**.

2. Press [CTRL] [F3] (SET UP) and then specify the default number system by pressing [F2] (Dec), [F3] (Hex), [F4] (Bin), or [F5] (Oct).

3. Press [ESC] to change to the screen for calculation input. This causes a function menu with the following items to appear.
   • {**d~o**}/{**LOGIC**}/{**DISP**}/{**SYBL**} ... {number system specification}/{bitwise operation}/{decimal/hexadecimal/binary/octal conversion}/{symbol} menu

■ Selecting a Number System

You can specify decimal, hexadecimal, binary, or octal as the default number system using the set up screen. After you press the function key that corresponds to the system you want to use, press [EXE].

● To specify a number system for an input value

You can specify a number system for each individual value you input. Press [F1](d~o) to display a menu of number system symbols. Press the function key that corresponds to the symbol you want to select and then input the value.

- {**d**}/{**h**}/{**b**}/{**o**} ... {decimal}/{hexadecimal}/{binary}/{octal}

● To input values of mixed number systems

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Example **To input 123_{10} or 1010_2, when the default number system is hexadecimal**

[CTRL] [F3](SET UP) [F3](Hex) [ESC]
[AC] [F1](d~o) [1](d) [1] [2] [3] [EXE]

```
d123
                    0000007B
```

[F1](d~o) [3](b) [1] [0] [1] [0] [EXE]

```
b1010
                    0000000A
```

■ Arithmetic Operations

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Example 1 **To calculate $10111_2 + 11010_2$**

[CTRL] [F3](SET UP) [F4](Bin) [ESC]
[AC] [1] [0] [1] [1] [1] [+]
[1] [1] [0] [1] [0] [EXE]

```
10111+11010
      0000000000110001
```

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Example 2 **To input and execute $123_8 \times ABC_{16}$, when the default number system is decimal or hexadecimal**

[CTRL] [F3] (SET UP) [F2] (Dec) [ESC]
[AC] [F1] (d~o) [4] (o) [1] [2] [3] [×]
[F1] (d~o) [2] (h) [A] [B] [C]*1 [EXE]

```
o123×hABC
                228084
```

[F3] (DISP) [2] (Hex) [EXE]

```
Ans▸Hex
            00037AF4
```

■ Negative Values and Bitwise Operations

Press [F2] (LOGIC) to display a menu of negation and bitwise operators.

- {**Neg**} ... {negation}*2
- {**Not**}/{**and**}/{**or**}/{**xor**}/{**xnor**} ... {NOT}*3/{AND}/{OR}/{XOR}/{XNOR}*4

• Negative Values

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Example **To determine the negative of 110010_2**

[CTRL] [F3] (SET UP) [F4] (Bin) [ESC]
[AC] [F2] (LOGIC) [1] (Neg)
[1] [1] [0] [0] [1] [0] [EXE]

```
Neg 110010
     1111111111001110
```

•Bitwise Operations

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Example 1 **To input and execute "120_{16} and AD_{16}"**

[CTRL] [F3] (SET UP) [F3] (Hex) [ESC]
[AC] [1] [2] [0] [F2] (LOGIC)
[3] (and) [A] [D] *1 [EXE]

```
120andAD
            00000020
```

*1 See page 2-7-1.
*2 two's complement
*3 one's complement (bitwise complement)
*4 bitwise AND, bitwise OR, bitwise XOR, bitwise XNOR

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Example 2 **To display the result of "36_8 or 1110_2" as an octal value**

[CTRL] [F3] (SET UP) [F5] (Oct) [ESC]
[AC] [3] [6] [F2] (LOGIC)
[4] (or) [F1] (d~o) [3] (b)
[1] [1] [1] [0] [EXE]

```
36orb1110
                00000000036
```

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Example 3 **To negate $2FFFED_{16}$**

[CTRL] [F3] (SET UP) [F3] (Hex) [ESC]
[AC] [F2] (LOGIC) [2] (Not)
[2] [F] [F] [F] [E] [D] *1 [EXE]

```
Not 2FFFED
                FFD00012
```

• Number System Transformation

Press [F3] (DISP) to display a menu of number system transformation functions.

- {**►Dec**}/{**►Hex**}/{**►Bin**}/{**►Oct**} ... transformation of displayed value to its {decimal}/{hexadecimal}/{binary}/{octal} equivalent

• To convert a displayed value from one number system to another

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Example **To convert 22_{10} (default number system) to its binary or octal value**

[AC] [CTRL] [F3] (SET UP) [F2] (Dec) [ESC]
[F1] (d~o) [1] (d) [2] [2] [EXE]

```
d22
                22
```

[F3] (DISP) [3] (►Bin) [EXE]

```
          0000000000010110
```

[F3] (DISP) [4] (►Oct) [EXE]

```
                00000000026
```

*1 See page 2-7-1.

2-8 Matrix Calculations

From the Main Menu, enter the **RUN • MAT** Mode, and press F1 (MAT) to perform Matrix calculations.

26 matrix memories (Mat A through Mat Z) plus a Matrix Answer Memory (MatAns), make it possible to perform the following matrix operations.

- Addition, subtraction, multiplication
- Scalar multiplication calculations
- Determinant calculations
- Matrix transposition
- Matrix inversion
- Matrix squaring
- Raising a matrix to a specific power
- Absolute value, integer part extraction, fractional part extraction, maximum integer calculations
- Matrix modification using matrix commands
- Absolute value, argument, complex conjugate calculation for a matrix with complex number components
- Real part and complex number part extraction of a matrix with complex number components

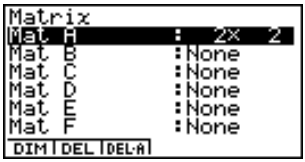
The maximum number of rows that can be specified for a matrix is 255, and the maximum number of columns is 255.

About Matrix Answer Memory (MatAns)
The calculator automatically stores matrix calculation results in Matrix Answer Memory. Note the following points about Matrix Answer Memory.

- Whenever you perform a matrix calculation, the current Matrix Answer Memory contents are replaced by the new result. The previous contents are deleted and cannot be recovered.
- Inputting values into a matrix does not affect Matrix Answer Memory contents.

■ Inputting and Editing Matrices

Pressing F1 (MAT) displays the matrix editor screen. Use the matrix editor to input and edit matrices.



$m \times n$ … m (row) × n (column) matrix

None… no matrix preset

- {**DIM**} ... {specifies the matrix dimensions (number of cells)}
- {**DEL**}/{**DEL·A**} ... deletes {a specific matrix}/{all matrices}

• Creating a Matrix

To create a matrix, you must first define its dimensions (size) in the Matrix list. Then you can input values into the matrix.

• To specify the dimensions (size) of a matrix

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Example **To create a 2-row × 3-column matrix in the area named Mat B**

Highlight Mat B.

▼

F1 (DIM)

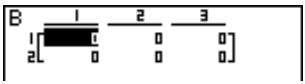
Specify the number of rows.

2 EXE

Specify the number of columns.

3 EXE

EXE



- All of the cells of a new matrix contain the value 0.

If "Memory ERROR" remains next to the matrix area name after you input the dimensions, it means there is not enough free memory to create the matrix you want.

• To input cell values

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Example **To input the following data into Matrix B :**

$$\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix}$$

(▼) (Selects Mat B.)

[EXE]

[1] [EXE] [2] [EXE] [3] [EXE]

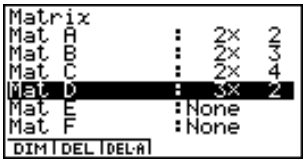
[4] [EXE] [5] [EXE] [6] [EXE]

(Data is input into the highlighted cell. Each time you press [EXE], the highlighting moves to the next cell to the right.)

You can input complex numbers into the cell of a matrix.
Displayed cell values show positive integers up to six digits, and negative integers up to five digits (one digit used for the negative sign). Exponential values are shown with up to two digits for the exponent. Fractional values are not displayed.
You can see the entire value assigned to a cell by using the cursor keys to move the highlighting to the cell whose value you want to view.
The amount of memory required for a matrix is 9 bytes per cell. This means that a 3×3 matrix requires 81 bytes of memory ($3 \times 3 \times 9 = 81$). Inputting complex numbers into a matrix doubles the amount of memory used.

• Deleting Matrices

You can delete either a specific matrix or all matrices in memory.



• To delete a specific matrix

1. While the Matrix list is on the display, use ▲ and ▼ to highlight the matrix you want to delete.
2. Press F2 (DEL).
3. Press EXE (Yes) to delete the matrix or ESC (No) to abort the operation without deleting anything.

• To delete all matrices

1. While the Matrix list is on the display, press F3 (DEL·A).
2. Press EXE (Yes) to delete all matrices in memory or ESC (No) to abort the operation without deleting anything.

The indicator "None" replaces the dimensions of the matrix you delete.

Inputting the format or changing the dimensions of a matrix deletes its current contents.

■ Matrix Cell Operations

Use the following procedure to prepare a matrix for cell operations.

1. While the Matrix list is on the display, use ▲ and ▼ to highlight the name of the matrix you want to use.
   You can jump to a specific matrix by inputting the letter that corresponds to the matrix name. Inputting [ALPHA] [8] (N), for example, jumps to Mat N.
   Pressing [SHIFT] [(−)] (Ans) jumps to the Matrix current Memory.
2. Press [EXE] and the function menu with the following items appears.
   - {**EDIT**} ... {cell editing screen}
   - {**R-OP**} ... {row operation menu}
   - {**R•DEL**}/{**R•INS**}/{**R•ADD**} ... row {delete}/{insert}/{add}
   - {**C•DEL**}/{**C•INS**}/{**C•ADD**} ... column {delete}/{insert}/{add}

All of the following examples use Matrix A.

• Row Calculations

The following menu appears whenever you press [F2] (R-OP) while a recalled matrix is on the display.

- {**Swap**} ... {row swap}
- {×**Row**} ... {product of specified row and scalar}
- {×**Row+**} ... {addition of one row and the product of a specified row with a scalar}
- {**Row+**} ... {addition of specified row to another row}

• To swap two rows

● ● ● ● ●

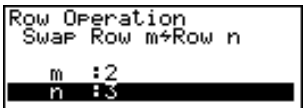
Example **To swap rows two and three of the following matrix :**

$$\text{Matrix A} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix}$$

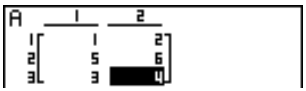
[F2] (R-OP) [1] (Swap)

Input the number of the rows you want to swap.

[2] [EXE] [3] [EXE]



[F6] (EXE) (or [EXE])



● To calculate the scalar multiplication of a row

● ● ● ● ●

Example **To calculate the product of row 2 of the following matrix and the scalar 4 :**

$$\text{Matrix A} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix}$$

F2 (R-OP) 2 (×Row)

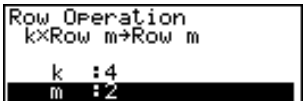
Input multiplier value.

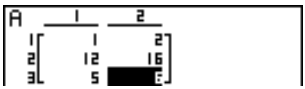
4 EXE

Specify row number.

2 EXE

F6 (EXE) (or EXE)





● To calculate the scalar multiplication of a row and add the result to another row

● ● ● ● ●

Example **To calculate the product of row 2 of the following matrix and the scalar 4, then add the result to row 3 :**

$$\text{Matrix A} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix}$$

F2 (R-OP) 3 (×Row+)

Input multiplier value.

4 EXE

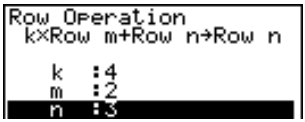
Specify number of row whose product should be calculated.

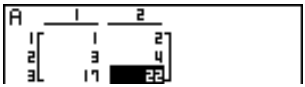
2 EXE

Specify number of row where result should be added.

3 EXE

F6 (EXE) (or EXE)





• To add two rows together

● ● ● ● ●

Example **To add row 2 to row 3 of the following matrix :**

$$\text{Matrix A} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix}$$

F2 (R-OP) 4 (Row+)

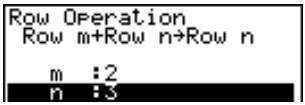
Specify number of row to be added.

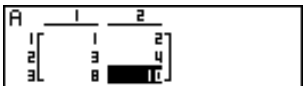
2 EXE

Specify number of row to be added to.

3 EXE

F6 (EXE) (or EXE)





• Row Operations

- {**R•DEL**} ... {delete row}
- {**R•INS**} ... {insert row}
- {**R•ADD**} ... {add row}

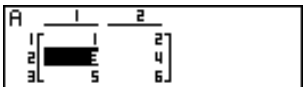
• To delete a row

● ● ● ● ●

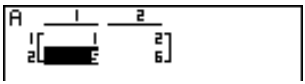
Example **To delete row 2 of the following matrix :**

$$\text{Matrix A} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix}$$

▼



F3 (R•DEL)



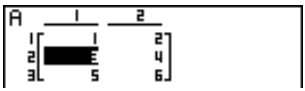
• To insert a row

● ● ● ● ●

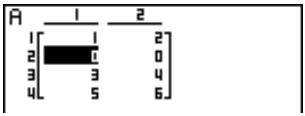
Example **To insert a new row between rows one and two of the following matrix :**

Matrix A = $\begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix}$

(▼)



F4 (R•INS)



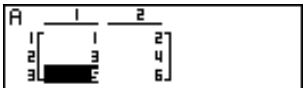
• To add a row

● ● ● ● ●

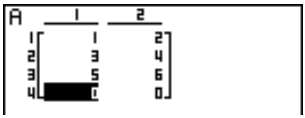
Example **To add a new row below row 3 of the following matrix :**

Matrix A = $\begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix}$

(▼)(▼)



F5 (R•ADD)



• Column Operations

- {**C•DEL**} ... {delete column}
- {**C•INS**} ... {insert column}
- {**C•ADD**} ... {add column}

• To delete a column

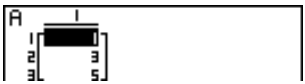
● ● ● ● ●

Example **To delete column 2 of the following matrix :**

$$\text{Matrix A} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix}$$

▶

F6 (▷) F1 (C•DEL)



• To insert a column

● ● ● ● ●

Example **To insert a new column between columns 1 and 2 of the following matrix :**

$$\text{Matrix A} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix}$$

▶

F6 (▷) F2 (C•INS)

• To add a column

● ● ● ● ●

Example **To add a new column to the right of column 2 of the following matrix :**

Matrix A = $\begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix}$

▶

F6 (▷) F3 (C•ADD)

■ Modifying Matrices Using Matrix Commands [OPTN]-[MAT]

• To display the matrix commands

1. From the Main Menu, enter the RUN • MAT Mode.
2. Press OPTN to display the option menu.
3. Press F2 (MAT) to display the matrix command menu.

The following describes only the matrix command menu items that are used for creating matrices and inputting matrix data.

- {**Mat**} ... {Mat command (matrix specification)}
- {**Dim**} ... {Dim command (dimension check)}
- {**Augmnt**} ... {Augment command (link two matrices)}
- {**Ident**} ... {Identity command (identity matrix input)}
- {**Fill**} ... {Fill command (identical cell values)}
- {**M→List**} ... {Mat→List command (assign contents of selected column to list file)}

• Matrix Data Input Format

[OPTN]-[MAT]-[Mat]

The following shows the format you should use when inputting data to create a matrix using the Mat command.

$$\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix}$$

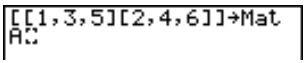
= [[a_{11}, a_{12}, ..., a_{1n}] [a_{21}, a_{22}, ..., a_{2n}] .... [a_{m1}, a_{m2}, ..., a_{mn}]]
→ Mat [letter A through Z]

● ● ● ● ●

Example 1 To input the following data as Matrix A :

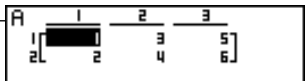
$$\begin{bmatrix} 1 & 3 & 5 \\ 2 & 4 & 6 \end{bmatrix}$$

[SHIFT] [+] ([ ) [SHIFT] [+] ([ ) [1] [,] [3] [,] [5]
[SHIFT] [−] ( ]) [SHIFT] [+] ([ ) [2] [,] [4] [,] [6]
[SHIFT] [−] ( ]) [SHIFT] [−] ( ]) [→] [OPTN] [F2] (MAT)
[1] (Mat) [ALPHA] [X,θ,T] (A)



[EXE]

Matrix name



You can also use [SHIFT] [2] (Mat) in place of [OPTN] [F2] (MAT) [1] (Mat).

The maximum value of both m and n is 255.

An error occurs if memory becomes full as you are inputting data.

You can also use the above format inside a program that inputs matrix data.

• To input an identity matrix

[OPTN]-[MAT]-[Ident]

Use the Identity command to create an identity matrix.

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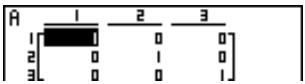
Example 2 **To create a 3 × 3 identity matrix as Matrix A**

[OPTN] [F2] (MAT) [6] (Ident)
[3] [→] [F2] (MAT) [1] (Mat) [ALPHA] [X,θ,T] (A) [EXE]
Number of rows/columns



• To check the dimensions of a matrix

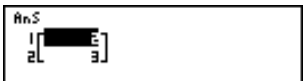
[OPTN]-[MAT]-[Dim]

Use the Dim command to check the dimensions of an existing matrix.

● ● ● ● ●

Example 3 **To check the dimensions of Matrix A, which was input in Example 1**

[OPTN] [F2] (MAT) [2] (Dim)
[F2] (MAT) [1] (Mat) [ALPHA] [X,θ,T] (A) [EXE]



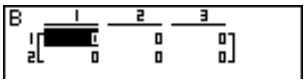
The display shows that Matrix A consists of two rows and three columns.

You can also use {Dim} to specify the dimensions of the matrix.

● ● ● ● ●

Example 4 **To specify dimensions of 2 rows and 3 columns for Matrix B**

[SHIFT] [×] ({) [2] [,] [3] [SHIFT] [÷] (}) [→]
[OPTN] [F2] (MAT) [2] (Dim)
[F2] (MAT) [1] (Mat) [ALPHA] [log] (B) [EXE]



• Modifying Matrices Using Matrix Commands

You can also use matrix commands to assign values to and recall values from an existing matrix, to fill in all cells of an existing matrix with the same value, to combine two matrices into a single matrix, and to assign the contents of a matrix column to a list file.

• To assign values to and recall values from an existing matrix

[OPTN]-[MAT]-[Mat]

Use the following format with the Mat command to specify a cell for value assignment and recall.

Mat X [m, n]

X ..... matrix name (A through Z, or Ans)

m ..... row number

n ..... column number

● ● ● ● ●

Example 1 **Assign 10 to the cell at row 1, column 2 of the following matrix :**

Matrix A = $\begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix}$

[1] [0] [→] [OPTN] [F2] (MAT) [1] (Mat)
[ALPHA] [X,θ,T] (A) [SHIFT] [+] ([ ) [1] [,] [2]
[SHIFT] [−] ( ]) [EXE]

```
10→Mat A[1,2]
                10
```

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Example 2 **Multiply the value in the cell at row 2, column 2 of the above matrix by 5**

[OPTN] [F2] (MAT) [1] (Mat)
[ALPHA] [X,θ,T] (A) [SHIFT] [+] ([ ) [2] [,] [2]
[SHIFT] [−] ( ]) [×] [5] [EXE]

```
Mat A[2,2]×5
                20
```

● To fill a matrix with identical values and to combine two matrices into a single matrix

[OPTN]-[MAT]-[Fill]/[Augmnt]

Use the Fill command to fill all the cells of an existing matrix with an identical value and the Augment command to combine two existing matrices into a single matrix.

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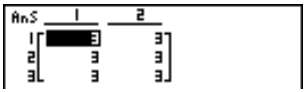
Example 1 **To fill all of the cells of Matrix A with the value 3**

[OPTN] [F2] (MAT) [7] (Fill)
[3] [,] [F2] (MAT) [1] (Mat) [ALPHA] [X,θ,T] (A) [EXE]
[F2] (MAT) [1] (Mat) [ALPHA] [X,θ,T] (A) [EXE]

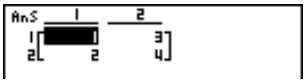


● ● ● ● ●

Example 2 **To combine the following two matrices :**

$$A = \begin{bmatrix} 1 \\ 2 \end{bmatrix} \qquad B = \begin{bmatrix} 3 \\ 4 \end{bmatrix}$$

[OPTN] [F2] (MAT) [5] (Augmnt)
[F2] (MAT) [1] (Mat) [ALPHA] [X,θ,T] (A) [,]
[F2] (MAT) [1] (Mat) [ALPHA] [log] (B) [EXE]



The two matrices you combine must have the same number of rows. An error occurs if you try to combine two matrices that have different numbers of rows.

• To assign the contents of a matrix column to a list

[OPTN]-[MAT]-[M→List]

Use the following format with the Mat→List command to specify a column and a list.

Mat → List (Mat X, m) → List n

X = matrix name (A through Z, or Ans)

m = column number

n = list number

● ● ● ● ●

Example **To assign the contents of column 2 of the following matrix to list 1 :**

$$\textbf{Matrix A} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix}$$

OPTN F2 (MAT) 8 (M→List)
F2 (MAT) 1 (Mat) ALPHA X,θ,T (A)) 2)
→ OPTN F1 (LIST) 1 (List) 1 EXE
OPTN F1 (LIST) 1 (List) 1 EXE

You can also use SHIFT 1 (List) in place of OPTN F1 (LIST) 1 (List).

You can use Matrix Answer Memory to assign the results of the above matrix input and edit operations to a matrix variable. To do so, use the following syntax.

- Fill (n, Mat α) → Mat β
- Augment (Mat α, Mat β) → Mat γ

In the above, α, β, and γ are any variable names A through Z, and n is any value.
The above does not affect the contents of Matrix Answer Memory.

■ Matrix Calculations

[OPTN]-[MAT]

Use the matrix command menu to perform matrix calculation operations.

• To display the matrix commands

1. From the Main Menu, enter the RUN • MAT Mode.
2. Press [OPTN] to display the option menu.
3. Press [F2] (MAT) to display the matrix command menu.

The following describes only the matrix commands that are used for matrix arithmetic operations.

- {**Mat**} ... {Mat command (matrix specification)}
- {**Det**} ... {Det command (determinant command)}
- {**Trn**} ... {Trn command (transpose matrix command)}
- {**Ident**} ... {Identity command (identity matrix input)}

All of the following examples assume that matrix data is already stored in memory.

• Matrix Arithmetic Operations

[OPTN]-[MAT]-[Mat]

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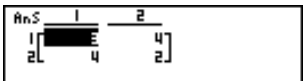
Example 1 **To add the following two matrices (Matrix A + Matrix B) :**

$$\mathbf{A} = \begin{bmatrix} 1 & 1 \\ 2 & 1 \end{bmatrix} \quad \mathbf{B} = \begin{bmatrix} 2 & 3 \\ 2 & 1 \end{bmatrix}$$

AC OPTN F2 (MAT) 1 (Mat) ALPHA X,θ,T (A) +
F2 (MAT) 1 (Mat) ALPHA log (B) EXE

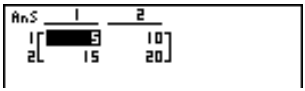


● ● ● ● ●

Example 2 **Calculate the product to the following matrix using a multiplier value of 5 :**

$$\text{Matrix A} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$$

AC 5 OPTN F2 (MAT) 1 (Mat)
ALPHA X,θ,T (A) EXE



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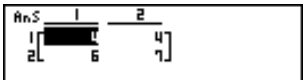
Example 3 **To multiply the two matrices in Example 1 (Matrix A × Matrix B)**

AC OPTN F2 (MAT) 1 (Mat) ALPHA X,θ,T (A) ×
F2 (MAT) 1 (Mat) ALPHA log (B) EXE

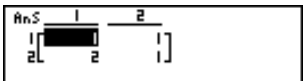


● ● ● ● ●

Example 4 **To multiply Matrix A (from Example 1) by a 2 × 2 identity matrix**

AC OPTN F2 (MAT) 1 (Mat) ALPHA X,θ,T (A) ×
F2 (MAT) 6 (Ident) 2 EXE

Number of rows and columns



The two matrices must have the same dimensions in order to be added or subtracted. An error occurs if you try to add or subtract matrices of different dimensions.

For multiplication (Matrix 1 × Matrix 2), the number of columns in Matrix 1 must match the number of rows in Matrix 2. Otherwise, an error occurs.

When performing matrix arithmetic operations, inputting the Identity command at the location of a matrix command (such as Mat A) makes it possible to perform identity matrix calculations.

• Determinant

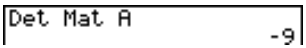
[OPTN]-[MAT]-[Det]

● ● ● ● ●

Example **Obtain the determinant for the following matrix :**

$$\text{Matrix A} = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ -1 & -2 & 0 \end{bmatrix}$$

[OPTN] [F2] (MAT) [3] (Det) [F2] (MAT) [1] (Mat)
[ALPHA] [X,θ,T] (A) [EXE]



• Matrix Transposition

[OPTN]-[MAT]-[Trn]

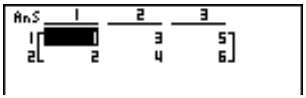
A matrix is transposed when its rows become columns and its columns become rows.

● ● ● ● ●

Example **To transpose the following matrix :**

$$\text{Matrix A} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix}$$

[OPTN] [F2] (MAT) [4] (Trn) [F2] (MAT) [1] (Mat)
[ALPHA] [X,θ,T] (A) [EXE]



Determinants can be obtained only for square matrices (same number of rows and columns). Trying to obtain a determinant for a matrix that is not square produces an error.

The determinant of a 2×2 matrix is calculated as shown below.

$$|A| = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} = a_{11}a_{22} - a_{12}a_{21}$$

The determinant of a 3×3 matrix is calculated as shown below.

$$|A| = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

$$= a_{11}a_{22}a_{33} + a_{12}a_{23}a_{31} + a_{13}a_{21}a_{32} - a_{11}a_{23}a_{32} - a_{12}a_{21}a_{33} - a_{13}a_{22}a_{31}$$

• Matrix Inversion

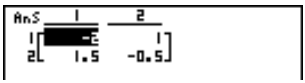
[OPTN]-[MAT]-[x^{-1}]

● ● ● ● ●

Example **To invert the following matrix :**

Matrix A = $\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$

OPTN F2 (MAT) 1 (Mat)
ALPHA X,θ,T (A) SHIFT) (x^{-1}) EXE



• Squaring a Matrix

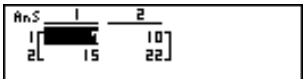
[OPTN]-[MAT]-[x^2]

● ● ● ● ●

Example **To square the following matrix :**

Matrix A = $\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$

OPTN F2 (MAT) 1 (Mat) ALPHA X,θ,T (A) x^2 EXE



Only square matrices (same number of rows and columns) can be inverted. Trying to invert a matrix that is not square produces an error.

A matrix with a determinant of zero cannot be inverted. Trying to invert a matrix with determinant of zero produces an error.

Calculation precision is affected for matrices whose determinant is near zero.

A matrix being inverted must satisfy the conditions shown below.

$$A A^{-1} = A^{-1} A = E = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

The following shows the formula used to invert Matrix A into inverse matrix A^{-1}.

$$A = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$$

$$A^{-1} = \frac{1}{ad - bc} \begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$$

Note that $ad - bc \neq 0$.

• Raising a Matrix to a Power

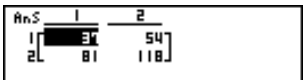
[OPTN]-[MAT]-[^]

● ● ● ● ●

Example **To raise the following matrix to the third power :**

$$\text{Matrix A} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$$

[OPTN] [F2] (MAT) [1] (Mat) [ALPHA] [X,θ,T] (A)
[^] [3] [EXE]



• Determining the Absolute Value, Integer Part, Fraction Part, and Maximum Integer of a Matrix

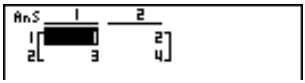
[OPTN]-[NUM]-[Abs]/[Frac]/[Int]/[Intg]

● ● ● ● ●

Example **To determine the absolute value of the following matrix :**

$$\text{Matrix A} = \begin{bmatrix} 1 & -2 \\ -3 & 4 \end{bmatrix}$$

[OPTN] [F5] (NUM) [1] (Abs)
[OPTN] [F2] (MAT) [1] (Mat) [ALPHA] [X,θ,T] (A) [EXE]



Determinants and inverse matrices are subject to error due to dropped digits.

Matrix operations are performed individually on each cell, so calculations may require considerable time to complete.

The calculation precision of displayed results for matrix calculations is ± 1 at the least significant digit.

If a matrix calculation result is too large to fit into Matrix Answer Memory, an error occurs.

You can use the following operation to transfer Matrix Answer Memory contents to another matrix (or when Matrix Answer Memory contains a determinant to a variable).

MatAns → Mat α

In the above, α is any variable name A through Z. The above does not affect the contents of Matrix Answer Memory.