

# INDEX

## Symbols

- + (addition operator), 2
- { } (curly brackets), to define a set, 122
- $\delta$  (delta), 184
- / (division operator), 2
- $\varepsilon$  (epsilon), 192, 197–199
- $=$  (equality operator), 124
- $e$  (Euler’s number), 179
- $**$  (exponential operator), 3
- // (floor division operator), 2–3
- j (imaginary number, in Python), 6
- $\int$  (integral), 200
- $\cap$  (intersection), 127
- $\lambda$  (lambda), 192, 197–199
- % (modulo operator), 3
- \* (multiplication operator), 2
- $\pi$  (pi), 129, 147
- (subtraction operator), 2
- $\theta$  (theta), 49
- $\rightarrow$  (transformation), 158
- $\cup$  (union), 126

## A

- abs() function, 7
- acos() function, 179
- algebraic expressions. *See* expressions
- Anaconda software installer, 213–214
- animation
  - of a growing circle, 153–155
  - of a projectile’s trajectory, 156–158
- animation module, 154
- Anscombe, Francis, “Graphs in Statistical Analysis,” 82

- Anscombe’s quartet, 82–83
- antiderivative, 200
- append() method, 30
- area
  - of a circle, estimating, 145–146
  - between two curves, 206–207
- asin() function, 179
- aspect ratio, 153
- atan() function, 179
- ATM example, 138–140
- attractors, 172

## B

- bar charts
  - for exercise, 57–59
  - for expenses, 56–57
- Barnsley fern, drawing, 163–168
- break, exiting with, 24

## C

- calculus. *See* functions
- cardinality, of a set, 122
- cards, shuffling deck of, 144–145
- Cartesian coordinates, 28–29
  - graph, 32
- Cartesian product, 127–128, 137
- causation, and correlation, 76
- circles
  - animating, 153–155
  - drawing, 151–153
  - estimating area of, 145–146
  - packing a square with, 168–169
- close() method, 231
- cmath module, 7
- code, reusing, 235–236
- coin tosses, 137–138, 144
- comma-separated value (CSV) files, 86–88

- complex numbers, 6–7  
    addition and subtraction of, 6  
    cmath module, 7  
    complex() function, 6  
    complex roots, 22  
    conjugate of, 7  
    conjugate() function, 7  
    magnitude, 7  
    Mandelbrot set, 172–176  
    real and `imag`, 7  
`components()` function, 226  
continuous compound interest, 183–184  
controlling program exit, 24  
correlation coefficients, 75–78, 89  
`cos()` function, 52, 178–179  
Counter class, 66  
CSV (comma-separated value) files, 86–88  
`csv` module, 86  
    `next()` function, 87  
    `reader()` function, 87  
curves  
    area between, 205–206  
    length of, 207–208
- D**
- data. *See also* sets, statistical measures  
    dispersion, measuring, 71–75  
    reading from files, 83–88  
deck of cards, shuffling, 144–145  
definite integral, 200–201, 203  
derivative, of a function, 185–191  
    calculator program, 186–187  
    higher-order, 188–191  
    partial, 187  
Derivative class, 185, 189  
dictionary, 100–101, 224–226, 227  
die rolls  
    game, 135–136  
    law of large numbers, 143–144  
    simulating, 134–135  
    target score, possibility of, 136–137
- discrete probability, 131–139  
dispersion of data, measuring, 71–75  
    range, finding, 71–72  
    variance and standard deviation, finding, 72–75  
distribution, uniform, 131  
domain, of a function, 178  
Droettboom, Michael,  
    “matplotlib,” 150
- E**
- `else` block, 230  
empty lists, 30  
`enumerate()` function, 31  
 $\text{epsilon } (\varepsilon)$ , 192, 197–199  
equations, solving, 20–22, 105–108  
    graphically, 115  
    linear, 20, 108  
    quadratic, 20–22, 106  
    `solve()` function, 105–108, 180, 199  
    for variables, 106–107  
Euler’s number ( $e$ ), 179  
even-odd vending machine, 22–23  
events (probability), 131  
exception handling, 9, 228–235  
    file reading errors, 232–235  
    multiple exception types, 228–229  
    `try...except`, 9, 228  
    `try...except...else`, 230  
    `ValueError`, 9, 12  
    `ZeroDivisionError`, 11, 228–229  
exit option, for programs, 24–26  
`exp()` function, 204  
expenses, visualizing with bar charts, 56–57  
experiments (probability), 131  
expressions, 96–105  
    factorizing and expanding, 96–97  
    multiplying, 104–105  
    plotting, 108–115  
        input by the user, 111–113  
    multiple, 113–115

pretty printing, 97–100  
strings, converting to, 103–105  
substituting in values, 100–103  
extrema, of a function, 188–191

**F**

`factor()` function, 96–97, 115  
factors of an integer,  
    calculating, 12–14  
`fargs` keyword argument, 154, 158  
Fibonacci sequence, 59–60  
file handling  
    `close()` method, 231  
    filename as input, 232  
    handling errors, 232–235  
    `open()` function, 231  
    reading files, 230–231  
    `readlines()` method, 232  
file object, 84  
formatting output, 15  
    `format()`, 15  
    number of digits, 16  
    `print()` function, 1  
fractals, 158–168  
    Barnsley fern, 163–168  
    Hénon’s function, 171–172  
    Mandelbrot set, 172–176  
    Sierpiński triangle, 170–171  
transformations of points,  
    158–163

fractions  
    calculator, 23–24  
    working with, 5–6

`fractions` module, 5

`frames` argument, 154, 158

frequency tables, creating, 69–71

`FuncAnimation` class, 154–158

functions (calculus), 178  
    common, 178–180  
    continuity at a point,  
        verifying, 205  
    derivatives of, finding, 185–187  
        higher-order, 188–191  
    domain of, 178  
    extrema of, 188–191

integrals of, finding, 200–201  
limit of, finding, 181–185  
probability density, 201–204  
range of, 178

## G

geometric shapes, drawing,  
    150–158  
geometric transformations, 158  
global maxima and minima,  
    188–199  
golden ratio, 59–60  
gradient ascent method, 191, 195  
gradient descent method, 199,  
    205–206  
graphs, creating with `matplotlib`,  
    32–46  
    customizing with titles and  
        labels, 41–44  
    marking points, 33–35  
    saving as images, 45–46  
    temperature data example,  
        35–44

## H

higher-order derivatives of  
    functions, finding,  
        188–191  
Hénon’s function, 171–172  
Hunter, John, “`matplotlib`,” 150

## I

IDLE, 1, 13–14  
    new program, 13  
    program execution, 14  
    running a program, 14  
    shell, 1  
importing, modules, 5  
`imshow()` function, 172  
indefinite integral, 200  
index, of a list, 29, 31  
inequalities, solving, 117–119  
infinite loop, 24  
`Infinity`, 183, 204

in operator, 122  
input() function, 8  
installation, of software  
    on Linux, 216–217  
    on Mac OS X, 217–220  
    on Windows, 214–215  
Integral class, 200  
integrals of functions, finding, 200  
intersection, of sets, 127  
interval argument, 154

## K

keys, in a dictionary, 224, 227

## L

labels, 4  
Lady ferns, 164  
law of large numbers, 144  
legend() function, 40  
len() function, 62  
limit, finding, 181  
Limit class, 182  
Linux, software installation on,  
    216–217  
lists, 29–31  
    appending to a list, 30  
    choosing a random  
        element, 161  
    creating a set, 123  
    empty lists, 30  
    index, 29  
    iterating over the elements, 31  
    len() function, 62  
    list comprehensions, 223–224  
    lists of lists, 173–175  
    max() function, 72  
    min() function, 72  
    sort() method, 64  
    sum() function, 62  
    tuples as members, 66  
    zip() function, 77  
local maxima and minima,  
    188–191  
log() function, 179

## M

Mac OS X, software installation on,  
    217–220  
Mandelbrot set, 172–176  
mathematical operations, 1–3  
    exponential operator, 3  
    floor division operator, 2  
    modulo (%) operator, 3, 12  
math module, 178  
matplotlib, 32  
    animation module, 154  
    axes  
        auto scaling, 152  
        customizing, 42  
    Axes object, 151  
    axis() function, 43  
    barh() function, 57  
    Circle patch, 151  
    colorbar() function, 175  
    displaying images, 172  
    documentation, 211  
    Figure object, 150, 154  
    FuncAnimation class, 154–158  
    gca() function, 152  
    gcf() function, 154  
    imshow() function, 172  
    labels, 41  
    legend, adding a, 40  
    legend() function, 40  
    marker, 34  
    multiple data sets, 38, 53  
    patches, 150  
    plot() function, 32, 36  
    Polygon patch, 168  
    pylab module, 32  
    pyplot module, 44  
    savefig() function, 45  
    saving, 45–46  
    scatter() function, 81  
    scatter plots, 79, 81–83  
    set\_aspect() method, 153  
    show() function, 32  
    title, 41  
    title() function, 41  
    xlabel() function, 41  
    ylabel() function, 41

maxima and minima, of functions, 188–191  
`max()` function, 72  
mean, finding, 62–63  
median, finding, 63–65  
`min()` function, 72  
mode, finding, 65–69  
modules, 5  
modulo (%) operator, 3  
multiplication tables, generating, 15–17, 23  
multiplying expressions, 104–105

## N

`_name__`, 221–223  
negative index, of a list, 31  
`NegativeInfinity`, 204  
Newton’s law of universal gravitation, 46–48  
number line, 28  
numbers  
    `abs()` function, 7  
    common number sets, 126  
    complex numbers. *See* complex numbers  
    conversion between types, 5  
    `float()` function, 5  
    floating point, 4–5  
    `Fraction` class, 5, 6  
    `fractions` module, 5  
    integers, 4–5  
    `int()` function, 5  
    `is_integer()` method, 10  
    random. *See* random numbers  
    rational, irrational, and real, 126  
    `type()` function, 4  
    types of, 4–7  
Nykamp, Duane Q., “The idea of a probability density function,” 202

## O

`open()` function, 231  
order of operations (PEMDAS), 3

## P

Packages (Python), 32  
partial derivative of functions, finding, 187  
Pearson correlation coefficient, 75  
PEMDAS (order of operations), 3  
pi ( $\pi$ ), estimating value of, 147  
`plot()` function, 32, 109  
plotting  
    expressions, 108–115  
        input by the user, 111–113  
        multiple, 113–115  
    with formulas, 46–54  
    projectile motion, 48–54  
        using SymPy. *See* SymPy  
polynomial expressions, 117  
`polynomial()` method, 119  
pretty printing, 97–100  
probability, 131–140, 201–204  
    continuous random variable, 201  
density functions, 201–204  
distribution, uniform, 131  
expectation, 143  
law of large numbers, 144  
nonuniform probability, 164  
random numbers. *See also* random numbers  
    generating, 134–137  
    nonuniform, 137–140  
    random variable, 143  
Project Euler, 210  
projectile motion, 48, 191  
    animation, 156  
    trajectory drawing, 51, 56  
`pylab` module, 32  
`pyplot` module, 44–45  
Python  
    documentation, 210, 211  
    IDLE, 1, 13–14  
    installation  
        Linux, 216–217  
        Mac OS X, 217–220  
        Windows, 214–215  
    overview, 221–236

## Q

- quadratic equations
  - finding the roots of, 20–22
  - solving, 106
- quadratic functions, exploring visually, 55–56

## R

- random module, 134
  - choice() function, 160
  - randint() function, 134, 175
  - random() function, 134
  - uniform() function, 146
- random numbers
  - ATM example, 138–140
  - coin tosses, 137–138, 144
  - deck of cards, shuffling, 144–145
  - die rolls. *See* die rolls
  - generating, 134–137
  - nonuniform, 137–140
- range
  - of a function, 178
  - of a set, 71–72
- range() function, 13, 37, 50
  - start, stop, and step values, 13
- rate of change, finding, 184
- reading data from files, 83–88
  - CSV files, 86–88
  - text files, 84–85
- return values, multiple, 226–228
- reusing code, 235–236
- Robertson, Ian, “Calculating Percentiles,” 90

## S

- sample spaces (probability), 131
- save() function, 111
- saving plots, as image files, 45–46, 111
- scatter plots, 79, 81–83
- series
  - calculating value of, 102–103
  - Fibonacci, 59–60
  - printing, 99–100
  - summing, 116
- set\_aspect() method, 153

## sets, 121–131

- cardinality, 122
- checking for a number in, 122
- common, 126
- correlation between, 75–81
- creating, 122–124
  - empty, 123
  - from lists or tuples, 123
- EmptySet object, 123
- FiniteSet class, 122
- FiniteSet object, 122
- intersect() method, 127
- is\_subset() method, 124
- is\_superset() method, 124
- iterating through the
  - members, 123
- operations, 126–131
  - Cartesian product, 127–128
  - formulas, using sets of variables in, 129
  - gravity example, 130–131
  - union and intersection, 126
- powerset() method, 125
- repetition and order, 123–124
- subsets, supersets, and power sets, 124–125
- union() method, 126–127
- Venn diagrams, 140–143
- show() function, 32, 111
- shuffling, deck of cards, 144–145
- Sierpiński triangle, 170–171
- simultaneous equations, 108
- sin() function, 52, 178, 179
- software installation
  - on Linux, 216–217
  - on Mac OS X, 217–220
  - on Windows, 214–215
- solving algebraic equations, 105
- standard deviation, finding, 72–75
- statistical measures
  - correlation coefficient, 75–81, 87
  - calculating, 76–78
  - high school grades example, 78–81
- dispersion, 71–75
- frequency tables, 69–71
  - grouped, 90–91

mean, 62–63  
median, 63–65  
mode, 65–71  
Pearson correlation  
    coefficient, 75  
percentile, 89–90  
range, 71–72  
    standard deviation, 72–75  
    variance, 72–75  
step size, 192, 197–199  
string, 8  
    format() method, 15  
    int() and float(), *See under*  
        numbers, 8  
strings to mathematical  
    expressions, 103  
**sum()** function, 62  
summing a series, 116  
symbolic math, 93  
**Sympy**  
    as\_numer\_denom() method, 118  
    assumptions, 180  
    Derivative class, 185  
    documentation, 98, 211  
    doit() method, 182, 185  
    expand() function, 96  
    expression, factorizing an, 96  
    factor() function, 96  
    init\_printing() function, 98  
    installation. *See* installation, of  
        software  
    Integral class, 200  
    is\_polynomial() method, 119  
    is\_rational\_function()  
        method, 119  
    Limit class, 182  
    plot() function, 109  
    plotting expressions with,  
        108–115  
        input by the user, 111–113  
        multiple, 113–115  
    Poly class, 117  
    pprint() function, 97–100  
    pretty printing, 97–100  
    save() function, 111  
    show() function, 111  
    simplify() function, 101  
    solve() function, 105, 106, 180  
    solve\_poly\_inequality()  
        function, 117  
    solve\_univariate\_inequality()  
        function, 118  
    solving inequalities, 117  
    S class, 182  
    subs() method, 100, 108, 184  
    summation() function, 116  
    symbol, defining a, 94  
    Symbol class, 94  
    symbols() function, 95  
    SympifyError class, 104  
    sympify() function, 103, 119, 186

## T

tan() function, 179  
title() function, 41–42  
trajectory (projectile motion)  
    comparing, 53–54, 56  
    drawing, 51–53  
transformation of a point, 158  
tuples, 29–31  
    empty, 31  
    iterating through the  
        members, 123

## U

union, of sets, 118, 126–127  
units of measurement, converting,  
    17–20, 23  
universal gravitation, Newton’s law,  
    46–48  
user input  
    complex() function, 12  
    fractional numbers, 11  
    getting, 8–12  
    handling invalid input, 9–11  
    input() function, 8

## V

ValueError, 9, 12  
variables, 4, 178  
    nonlinear relationship, 47  
variance, finding, 72–75  
Venn diagrams, 140–143

## **W**

`while` loop, 24  
    exiting early using `break`, 24  
`Windows`, software installation on,  
    214–215

## **Z**

`ZeroDivisionError`, 11, 228–229  
`zip()` function, 77