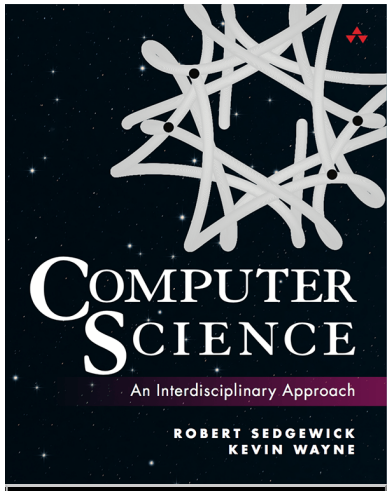


INTRO TO PROGRAMMING

1. Elements of Programming
2. Functions
3. OOP
4. Data Structures

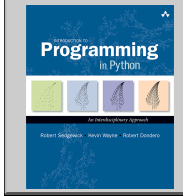
COMPUTER SCIENCE

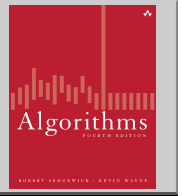
5. Theory of Computing
6. A Computing Machine
7. Building a Computer

BEYOND

8. Systems
9. Scientific Computation

RELATED BOOKSITES

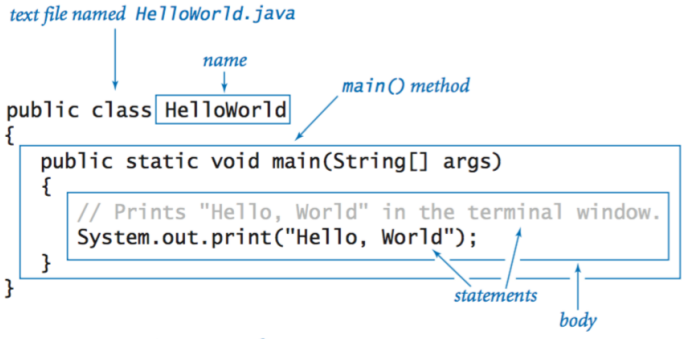




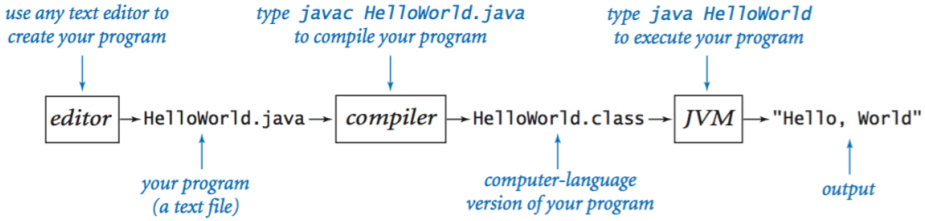
JAVA PROGRAMMING CHEATSHEET

We summarize the most commonly used Java language features and APIs in the textbook.

Hello, World.



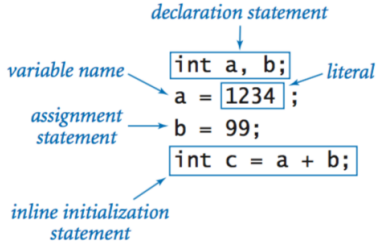
Editing, compiling, and executing.



Built-in data types.

type	*set of values*	*common operators*	*sample literal values*
`int`	integers	`+ - * / %`	`99 12 2147483647`
`double`	floating-point numbers	`+ - * /`	`3.14 2.5 6.022e23`
`boolean`	boolean values	`&& || !`	`true false`
`char`	characters		`'A' '1' '%' '\n'`
`String`	sequences of characters	`+`	`"AB" "Hello" "2.5"`

Declaration and assignment statements.



Integers.

values	integers between -2^{31} and $+2^{31}-1$					
typical literals	`1234 99 0 1000000`					
operations	*sign*	*add*	*subtract*	*multiply*	*divide*	*remainder*
operators	`+ -`	`+`	`-`	`*`	`/`	`%`

expression	*value*	*comment*
`99`	`99`	*integer literal*
`+99`	`99`	*positive sign*
`-99`	`-99`	*negative sign*
`5 + 3`	`8`	*addition*
`5 - 3`	`2`	*subtraction*
`5 * 3`	`15`	*multiplication*
`5 / 3`	`1`	*no fractional part*
`5 % 3`	`2`	*remainder*
`1 / 0`		*run-time error*
`3 * 5 - 2`	`13`	** has precedence*
`3 + 5 / 2`	`5`	*/ has precedence*
`3 - 5 - 2`	`-4`	*left associative*
`( 3 - 5 ) - 2`	`-4`	*better style*
`3 - ( 5 - 2 )`	`0`	*unambiguous*

Floating-point numbers.

values	real numbers (specified by IEEE 754 standard)			
typical literals	`3.14159`	`6.022e23`	`2.0`	`1.4142135623730951`
operations	*add*	*subtract*	*multiply*	*divide*
operators	`+`	`-`	`*`	`/`

expression	*value*
`3.141 + 2.0`	`5.141`
`3.141 - 2.0`	`1.111`
`3.141 / 2.0`	`1.5705`
`5.0 / 3.0`	`1.6666666666666667`
`10.0 % 3.141`	`0.577`
`1.0 / 0.0`	`Infinity`
`Math.sqrt(2.0)`	`1.4142135623730951`
`Math.sqrt(-1.0)`	`NaN`

Booleans.

values	*true or false*		
literals	`true`	`false`	
operations	and	or	not
operators	&&	||	!

a	*!a*
`true`	`false`
`false`	`true`

a	*b*	*a && b*	*a || b*
`false`	`false`	`false`	`false`
`false`	`true`	`false`	`true`
`true`	`false`	`false`	`true`
`true`	`true`	`true`	`true`

Comparison operators.

op	*meaning*	*true*	*false*
`==`	*equal*	`2 == 2`	`2 == 3`
`!=`	*not equal*	`3 != 2`	`2 != 2`
`<`	*less than*	`2 < 13`	`2 < 2`
`<=`	*less than or equal*	`2 <= 2`	`3 <= 2`
`>`	*greater than*	`13 > 2`	`2 > 13`
`>=`	*greater than or equal*	`3 >= 2`	`2 >= 3`

non-negative discriminant?	`(b*b - 4.0*a*c) >= 0.0`
beginning of a century?	`(year % 100) == 0`
legal month?	`(month >= 1) && (month <= 12)`

Printing.

`void System.out.print(String s)`	*print s*
`void System.out.println(String s)`	*print s, followed by a newline*
`void System.out.println()`	*print a newline*

Parsing command-line arguments.

`int`	`Integer.parseInt(String s)`	*convert `s` to an `int` value*
`double`	`Double.parseDouble(String s)`	*convert `s` to a `double` value*
`long`	`Long.parseLong(String s)`	*convert `s` to a `long` value*

Math library.

`public class Math`		
`double`	`abs(double a)`	*absolute value of `a`*
`double`	`max(double a, double b)`	*maximum of `a` and `b`*
`double`	`min(double a, double b)`	*minimum of `a` and `b`*
`double`	`sin(double theta)`	*sine of `theta`*
`double`	`cos(double theta)`	*cosine of `theta`*
`double`	`tan(double theta)`	*tangent of `theta`*
`double`	`toRadians(double degrees)`	*convert angle from degrees to radians*
`double`	`toDegrees(double radians)`	*convert angle from radians to degrees*
`double`	`exp(double a)`	*exponential (e^a)*
`double`	`log(double a)`	*natural log ($\log_e a$, or $\ln a$)*
`double`	`pow(double a, double b)`	*raise `a` to the `b`th power (a^b)*
`long`	`round(double a)`	*round `a` to the nearest integer*
`double`	`random()`	*random number in $[0, 1)$*
`double`	`sqrt(double a)`	*square root of `a`*
`double`	`E`	*value of e (constant)*
`double`	`PI`	*value of π (constant)*

The full java.lang.Math API.

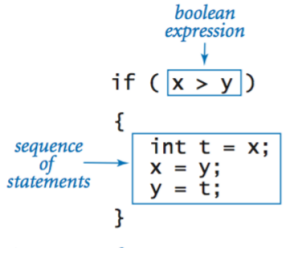
Java library calls.

method call	*library*	*return type*	*value*
`Integer.parseInt("123")`	`Integer`	`int`	`123`
`Double.parseDouble("1.5")`	`Double`	`double`	`1.5`
`Math.sqrt(5.0*5.0 - 4.0*4.0)`	`Math`	`double`	`3.0`
`Math.log(Math.E)`	`Math`	`double`	`1.0`
`Math.random()`	`Math`	`double`	*random in* [0, 1)
`Math.round(3.14159)`	`Math`	`long`	`3`
`Math.max(1.0, 9.0)`	`Math`	`double`	`9.0`

Type conversion.

expression	*expression type*	*expression value*
`(1 + 2 + 3 + 4) / 4.0`	`double`	`2.5`
`Math.sqrt(4)`	`double`	`2.0`
`"1234" + 99`	`String`	`"123499"`
`11 * 0.25`	`double`	`2.75`
`(int) 11 * 0.25`	`double`	`2.75`
`11 * (int) 0.25`	`int`	`0`
`(int) (11 * 0.25)`	`int`	`2`
`(int) 2.71828`	`int`	`2`
`Math.round(2.71828)`	`long`	`3`
`(int) Math.round(2.71828)`	`int`	`3`
`Integer.parseInt("1234")`	`int`	`1234`

Anatomy of an if statement.



If and if-else statements.

absolute value	`if (x < 0) x = -x;`

put the smaller value in x and the larger value in y	`if (x > y)`
	`{`
	`  int t = x;`
	`  x = y;`
	`  y = t;`
	`}`

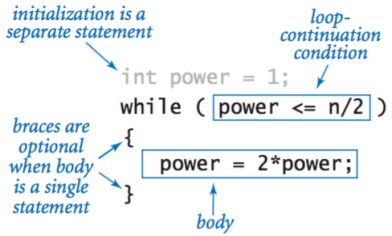
maximum of x and y	`if (x > y) max = x;` `else  max = y;`
error check for division operation	`if (den == 0) System.out.println("Division by zero");` `else  System.out.println("Quotient = " + num/den);`

error check for quadratic formula	`double discriminant = b*b - 4.0*c;`
	`if (discriminant < 0.0)`
	`{`
	`  System.out.println("No real roots");`
	`}`
	`else`
	`{`
	`  System.out.println((-b + Math.sqrt(discriminant))/2.0);`
	`  System.out.println((-b - Math.sqrt(discriminant))/2.0);`
	`}`

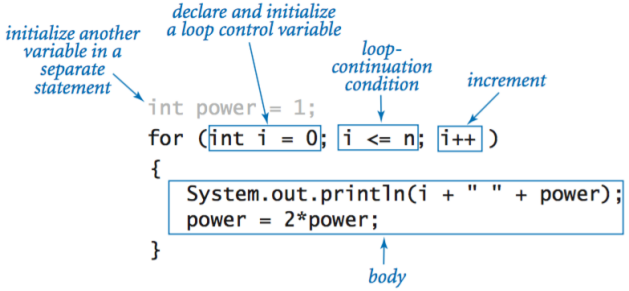
Nested if-else statement.

```
if      (income <      0) rate = 0.00;
else if (income <   8925) rate = 0.10;
else if (income <  36250) rate = 0.15;
else if (income <  87850) rate = 0.23;
else if (income < 183250) rate = 0.28;
else if (income < 398350) rate = 0.33;
else if (income < 400000) rate = 0.35;
else                      rate = 0.396;
```

Anatomy of a while loop.



Anatomy of a for loop.



Loops.

compute the largest power of 2 less than or equal to n	`int power = 1;`
	`while (power <= n/2)`
	`  power = 2*power;`
	`System.out.println(power);`

compute a finite sum (1 + 2 + ... + n)	`int sum = 0;`
	`for (int i = 1; i <= n; i++)`
	`  sum += i;`
	`System.out.println(sum);`

compute a finite product (n! = 1 × 2 × ... × n)	`int product = 1;`
	`for (int i = 1; i <= n; i++)`
	`  product *= i;`
	`System.out.println(product);`

print a table of function values	`for (int i = 0; i <= n; i++)` `  System.out.println(i + " " + 2*Math.PI*i/n);`

compute the ruler function (see PROGRAM 1.2.1)	`String ruler = "1";`
	`for (int i = 2; i <= n; i++)`
	`  ruler = ruler + " " + i + " " + ruler;`
	`System.out.println(ruler);`

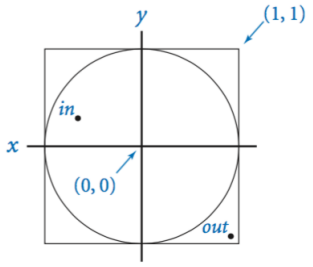
Break statement.

```
int factor;
for (factor = 2; factor <= n/factor; factor++)
   if (n % factor == 0) break;

if (factor > n/factor)
   System.out.println(n + " is prime");
```

Do-while loop.

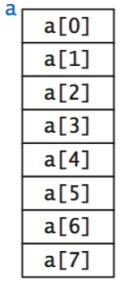
```
do
{  // Scale x and y to be random in (-1, 1).
   x = 2.0*Math.random() - 1.0;
   y = 2.0*Math.random() - 1.0;
} while (Math.sqrt(x*x + y*y) > 1.0);
```



Switch statement.

```
switch (day) {
   case 0: System.out.println("Sun"); break;
   case 1: System.out.println("Mon"); break;
   case 2: System.out.println("Tue"); break;
   case 3: System.out.println("Wed"); break;
   case 4: System.out.println("Thu"); break;
   case 5: System.out.println("Fri"); break;
   case 6: System.out.println("Sat"); break;
}
```

Arrays.



Inline array initialization.

```
String[] SUITS = { "Clubs", "Diamonds", "Hearts", "Spades" };

String[] RANKS = {
   "2", "3", "4", "5", "6", "7", "8", "9", "10",
   "Jack", "Queen", "King", "Ace"
};
```

Typical array-processing code.

create an array with random values	`double[] a = new double[n];`
	`for (int i = 0; i < n; i++)`
	`  a[i] = Math.random();`

print the array values, one per line	`for (int i = 0; i < n; i++)` `  System.out.println(a[i]);`

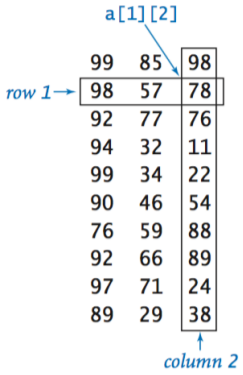
find the maximum of the array values	`double max = Double.NEGATIVE_INFINITY;`
	`for (int i = 0; i < n; i++)`
	`  if (a[i] > max) max = a[i];`

compute the average of the array values	`double sum = 0.0;`
	`for (int i = 0; i < n; i++)`
	`  sum += a[i];`
	`double average = sum / n;`

reverse the values within an array	`for (int i = 0; i < n/2; i++)`
	`{`
	`  double temp = a[i];`
	`  a[i] = a[n-1-i];`
	`  a[n-i-1] = temp;`
	`}`

copy sequence of values to another array	`double[] b = new double[n];`
	`for (int i = 0; i < n; i++)`
	`  b[i] = a[i];`

Two-dimensional arrays.



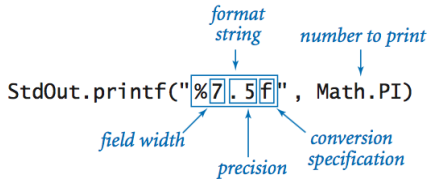
Inline initialization.

```
double [][] a =
{
   { 99.0, 85.0, 98.0,  0.0 },
   { 98.0, 57.0, 79.0,  0.0 },
   { 92.0, 77.0, 74.0,  0.0 },
   { 94.0, 62.0, 81.0,  0.0 },
   { 99.0, 94.0, 92.0,  0.0 },
   { 80.0, 76.5, 67.0,  0.0 },
   { 76.0, 58.5, 90.5,  0.0 },
   { 92.0, 66.0, 91.0,  0.0 },
   { 97.0, 70.5, 66.5,  0.0 },
   { 89.0, 89.5, 81.0,  0.0 },
   {  0.0,  0.0,  0.0,  0.0 }
};
```

Our standard output library.

public class StdOut	
void print(String s)	*print* `s` *to standard output*
void println(String s)	*print* `s` *and a newline to standard output*
void println()	*print a newline to standard output*
void printf(String format, ...)	*print the arguments to standard output, as specified by the format string* `format`

The full StdOut API.



type	code	typical literal	sample format strings	converted string values for output
int	d	512	"%14d" "%-14d"	" 512" "512 "
double	f e	1595.1680010754388	"%14.2f" "%.7f" "%14.4e"	" 1595.17" "1595.1680011" " 1.5952e+03"
String	s	"Hello, World"	"%14s" "%-14s" "%-14.5s"	" Hello, World" "Hello, World " "Hello "
boolean	b	true	"%b"	"true"

Our standard input library.

public class StdIn	
methods for reading individual tokens from standard input	
`boolean` `isEmpty()`	*is standard input empty (or only whitespace)?*
`int` `readInt()`	*read a token, convert it to an `int`, and return it*
`double` `readDouble()`	*read a token, convert it to a `double`, and return it*
`boolean` `readBoolean()`	*read a token, convert it to a `boolean`, and return it*
`String` `readString()`	*read a token and return it as a `String`*
methods for reading characters from standard input	
`boolean` `hasNextChar()`	*does standard input have any remaining characters?*
`char` `readChar()`	*read a character from standard input and return it*
methods for reading lines from standard input	
`boolean` `hasNextLine()`	*does standard input have a next line?*
`String` `readLine()`	*read the rest of the line and return it as a `String`*
methods for reading the rest of standard input	
`int[]` `readAllInts()`	*read all remaining tokens and return them as an `int` array*
`double[]` `readAllDoubles()`	*read all remaining tokens and return them as a `double` array*
`boolean[]` `readAllBooleans()`	*read all remaining tokens and return them as a `boolean` array*
`String[]` `readAllStrings()`	*read all remaining tokens and return them as a `String` array*
`String[]` `readAllLines()`	*read all remaining lines and return them as a `String` array*
`String` `readAll()`	*read the rest of the input and return it as a `String`*

The full StdIn API.

Our standard drawing library.

public class StdDraw	
drawing commands	
void line(double x0, double y0, double x1, double y1)	
void point(double x, double y)	
void circle(double x, double y, double radius)	
void filledCircle(double x, double y, double radius)	
void square(double x, double y, double radius)	
void filledSquare(double x, double y, double radius)	
void rectangle(double x, double y, double r1, double r2)	
void filledRectangle(double x, double y, double r1, double r2)	
void polygon(double[] x, double[] y)	
void filledPolygon(double[] x, double[] y)	
void text(double x, double y, String s)	
control commands	
void setXscale(double x0, double x1)	*reset x-scale to (`x0`, `x1`)*
void setYscale(double y0, double y1)	*reset y-scale to (`y0`, `y1`)*
void setPenRadius(double radius)	*set pen radius to `radius`*
void setPenColor(Color color)	*set pen color to `color`*
void setFont(Font font)	*set text font to `font`*
void setCanvasSize(int w, int h)	*set canvas size to w-by-h*
void enableDoubleBuffering()	*enable double buffering*
void disableDoubleBuffering()	*disable double buffering*
void show()	*copy the offscreen canvas to the onscreen canvas*
void clear(Color color)	*clear the canvas to color `color`*
void pause(int dt)	*pause `dt` milliseconds*
void save(String filename)	*save to a `.jpg` or `.png` file*

The full StdDraw API.

Our standard audio library.

```
public class StdAudio
```

`void play(String filename)`	*play the given .wav file*
`void play(double[] a)`	*play the given sound wave*
`void play(double x)`	*play sample for 1/44100 second*
`void save(String filename, double[] a)`	*save to a .wav file*
`double[] read(String filename)`	*read from a .wav file*

The full StdAudio API.

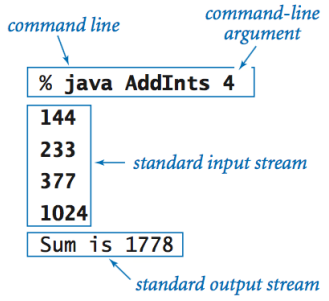
Command line.

```
public class AddInts
{
   public static void main(String[] args)
   {
      int n = Integer.parseInt(args[0]);
      int sum = 0;
      for (int i = 0; i < n; i++)
      {
         int value = StdIn.readInt();
         sum += value;
      }
      StdOut.println("Sum is " + sum);
   }
}
```

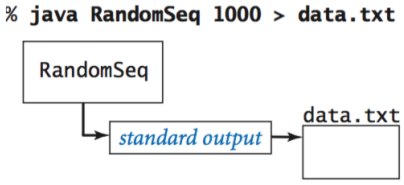
parse command-line argument

read from standard input stream

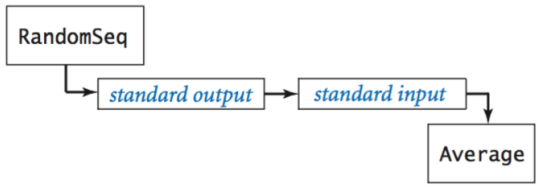
print to standard output stream



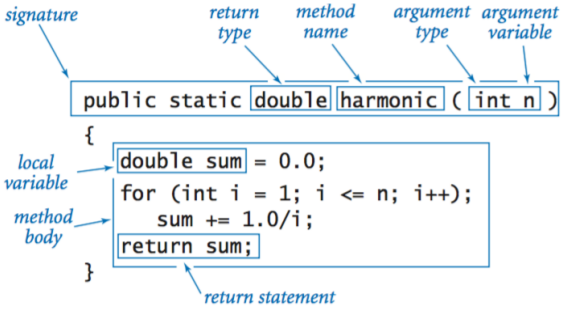
Redirection and piping.



```
% java RandomSeq 1000 | java Average
```



Functions.



absolute value of an `int` value

```
public static int abs(int x)
{
   if (x < 0) return -x;
   else       return  x;
}
```

absolute value of a `double` value

```
public static double abs(double x)
{
   if (x < 0.0) return -x;
   else         return  x;
}
```

primality test

```
public static boolean isPrime(int n)
{
   if (n < 2) return false;
   for (int i = 2; i <= n/i; i++)
      if (n % i == 0) return false;
   return true;
}
```

hypotenuse of a right triangle

```
public static double hypotenuse(double a, double b)
{  return Math.sqrt(a*a + b*b);  }
```

harmonic number

```
public static double harmonic(int n)
{
   double sum = 0.0;
   for (int i = 1; i <= n; i++)
      sum += 1.0 / i;
   return sum;
}
```

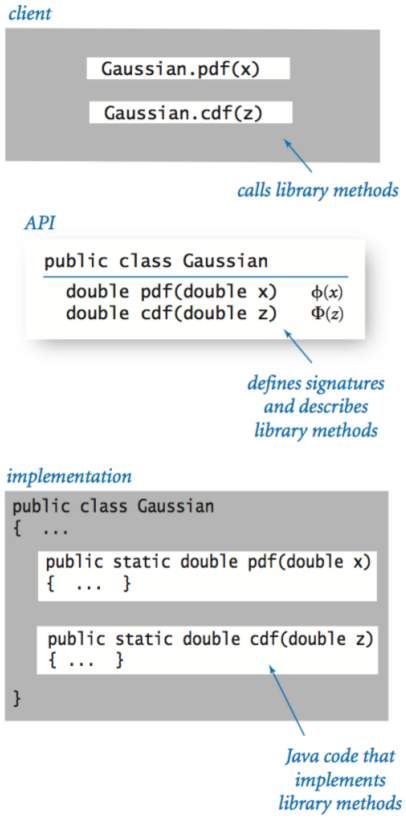
uniform random integer in [0, n)

```
public static int uniform(int n)
{  return (int) (Math.random() * n);  }
```

draw a triangle

```
public static void drawTriangle(double x0, double y0,
                                double x1, double y1,
                                double x2, double y2 )
{
   StdDraw.line(x0, y0, x1, y1);
   StdDraw.line(x1, y1, x2, y2);
   StdDraw.line(x2, y2, x0, y0);
}
```

Libraries of functions.



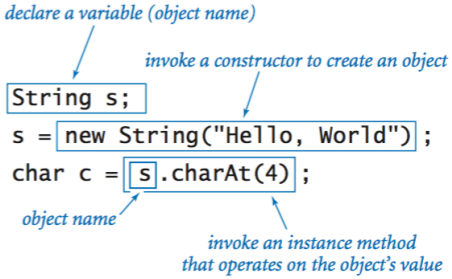
Our standard random library.

public class StdRandom	
void setSeed(long seed)	*set the seed for reproducible results*
int uniform(int n)	*integer between 0 and n-1*
double uniform(double lo, double hi)	*real between lo and hi*
boolean bernoulli(double p)	*true with probability p*
double gaussian()	*normal, mean 0, standard deviation 1*
double gaussian(double mu, double sigma)	*normal, mean mu, standard deviation sigma*
int discrete(double[] probabilities)	*i with probability probabilities[i]*
void shuffle(double[] a)	*randomly shuffle the array a[]*

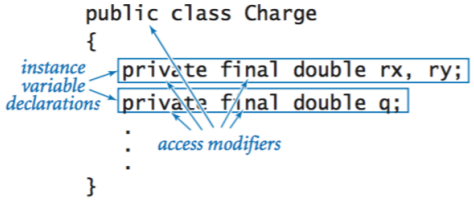
Our standard statistics library.

public class StdStats	
double max(double[] a)	*largest value*
double min(double[] a)	*smallest value*
double mean(double[] a)	*average*
double var(double[] a)	*sample variance*
double stddev(double[] a)	*sample standard deviation*
double median(double[] a)	*median*
void plotPoints(double[] a)	*plot points at (i, a[i])*
void plotLines(double[] a)	*plot lines connecting (i, a[i])*
void plotBars(double[] a)	*plot bars to points at (i, a[i])*

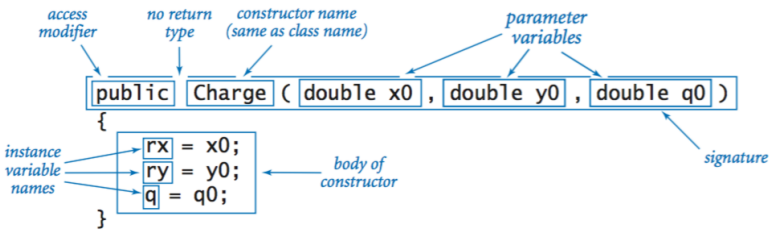
Using an object.



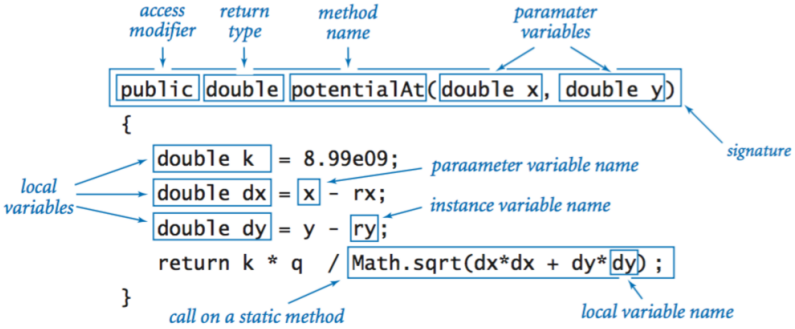
Instance variables.



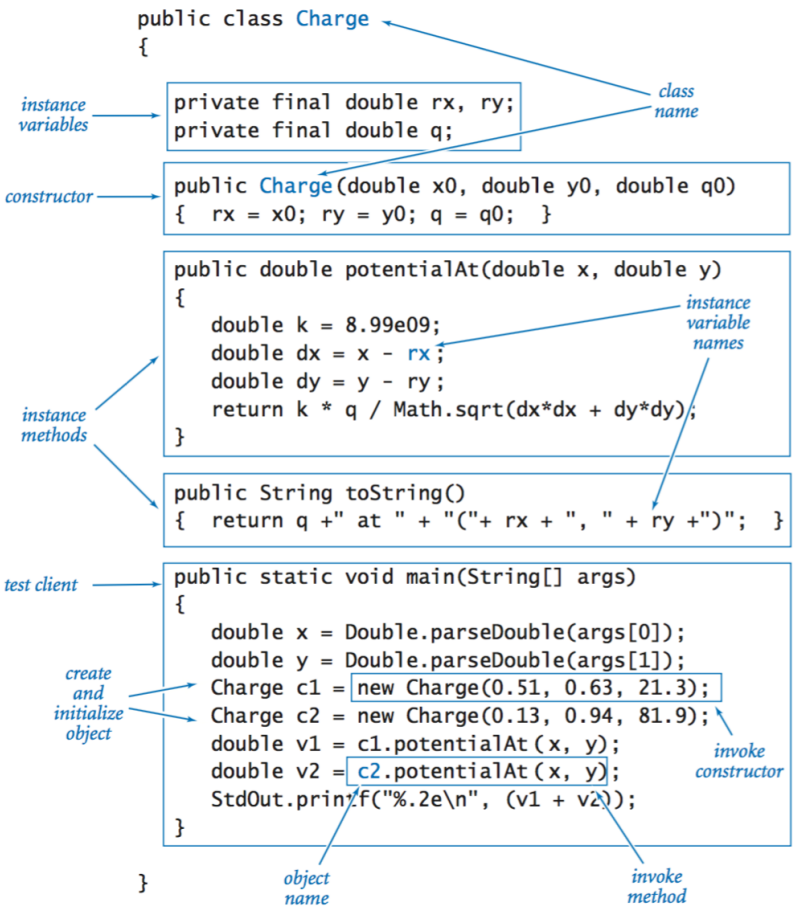
Constructors.



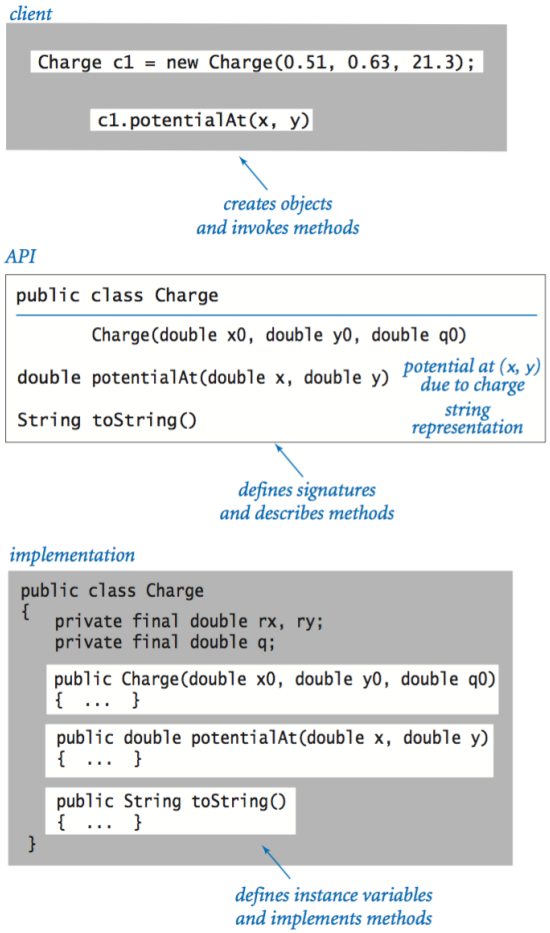
Instance methods.



Classes.



Object-oriented libraries.



Java's String data type.

public class String	
String(String s)	*create a string with the same value as* `s`
String(char[] a)	*create a string that represents the same sequence of characters as in* `a[]`
int length()	*number of characters*
char charAt(int i)	*the character at index* `i`
String substring(int i, int j)	*characters at indices* `i` *through* `(j-1)`
boolean contains(String substring)	*does this string contain* `substring`*?*
boolean startsWith(String prefix)	*does this string start with* `prefix`*?*
boolean endsWith(String postfix)	*does this string end with* `postfix`*?*
int indexOf(String pattern)	*index of first occurrence of* `pattern`
int indexOf(String pattern, int i)	*index of first occurrence of* `pattern` *after* `i`
String concat(String t)	*this string, with* `t` *appended*
int compareTo(String t)	*string comparison*
String toLowerCase()	*this string, with lowercase letters*
String toUpperCase()	*this string, with uppercase letters*
String replace(String a, String b)	*this string, with* `a`*s replaced by* `b`*s*
String trim()	*this string, with leading and trailing whitespace removed*
boolean matches(String regexp)	*is this string matched by the regular expression?*
String[] split(String delimiter)	*strings between occurrences of* `delimiter`
boolean equals(Object t)	*is this string's value the same as* `t`*'s?*
int hashCode()	*an integer hash code*

The full java.lang.String API  .

```
String a = new String("now is");
String b = new String("the time");
String c = new String(" the");
```

instance method call	*return type*	*return value*
`a.length()`	`int`	`6`
`a.charAt(4)`	`char`	`'i'`
`a.substring(2, 5)`	`String`	`"w i"`
`b.startsWith("the")`	`boolean`	`true`
`a.indexOf("is")`	`int`	`4`
`a.concat(c)`	`String`	`"now is the"`
`b.replace("t", "T")`	`String`	`"The Time"`
`a.split(" ")`	`String[]`	`{ "now", "is" }`
`b.equals(c)`	`boolean`	`false`

Java's Color data type.

`public class java.awt.Color`		
	`Color(int r, int g, int b)`	
`int`	`getRed()`	*red intensity*
`int`	`getGreen()`	*green intensity*
`int`	`getBlue()`	*blue intensity*
`Color`	`brighter()`	*brighter version of this color*
`Color`	`darker()`	*darker version of this color*
`String`	`toString()`	*string representation of this color*
`boolean`	`equals(Object c)`	*is this color's value the same as c ?*

The full java.awt.Color API.

Our input library.

public class In	
In()	*create an input stream from standard input*
In(String name)	*create an input stream from a file or website*
instance methods that read individual tokens from the input stream	
boolean isEmpty()	*is standard input empty (or only whitespace)?*
int readInt()	*read a token, convert it to an* `int`*, and return it*
double readDouble()	*read a token, convert it to a* `double`*, and return it*
...	
instance methods that read characters from the input stream	
boolean hasNextChar()	*does standard input have any remaining characters?*
char readChar()	*read a character from standard input and return it*
instance methods that read lines from the input stream	
boolean hasNextLine()	*does standard input have a next line?*
String readLine()	*read the rest of the line and return it as a* `String`
instance methods that read the rest of the input stream	
int[] readAllInts()	*read all remaining tokens; return as array of integers*
double[] readAllDoubles()	*read all remaining tokens; return as array of doubles*
...	

The full In API.

Our output library.

public class Out	
Out()	*create an output stream to standard output*
Out(String name)	*create an output stream to a file*
void print(String s)	*print* `s` *to the output stream*
void println(String s)	*print* `s` *and a newline to the output stream*
void println()	*print a newline to the output stream*
void printf(String format, ...)	*print the arguments to the output stream, as specified by the format string* `format`

The full Out API.

Our picture library.

public class Picture	
Picture(String filename)	*create a picture from a file*
Picture(int w, int h)	*create a blank w-by-h picture*
int width()	*return the width of the picture*
int height()	*return the height of the picture*
Color get(int col, int row)	*return the color of pixel (col, row)*
void set(int col, int row, Color color)	*set the color of pixel (col, row) to color*
void show()	*display the picture in a window*
void save(String filename)	*save the picture to a file*

The full Picture API.

Our stack data type.

public class Stack<Item> implements Iterable<Item>	
Stack()	*create an empty stack*
boolean isEmpty()	*is the stack empty?*
void push(Item item)	*push an item onto the stack*
Item pop()	*return and remove the item that was inserted most recently*
int size()	*number of items on stack*

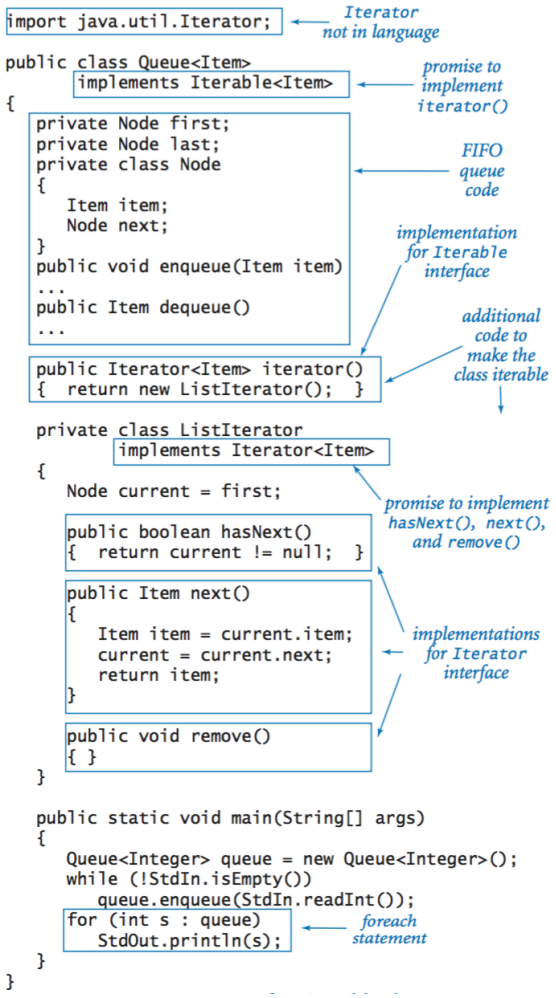
The full Stack API.

Our queue data type.

public class Queue<Item> implements Iterable<Item>	
Queue()	*create an empty queue*
boolean isEmpty()	*is the queue empty?*
void enqueue(Item item)	*insert an item onto queue*
Item dequeue()	*return and remove the item that was inserted least recently*
int size()	*number of items on queue*

The full Queue API.

Iterable.



Our symbol table data type.

public class ST<Key extends Comparable<Key>, Value>	
ST()	*create an empty symbol table*
void put(Key key, Value val)	*associate* `val` *with* `key`
Value get(Key key)	*value associated with* `key`
void remove(Key key)	*remove* `key` *(and its associated value)*
boolean contains(Key key)	*is there a value associated with* `key`*?*
int size()	*number of key–value pairs*
Iterable<Key> keys()	*all keys in the symbol table*

The full ST API.

Our set data type.

public class SET<Key extends Comparable<Key>> implements Iterable<Key>	
SET()	*create an empty set*
boolean isEmpty()	*is the set empty?*
void add(Key key)	*add* `key` *to the set*
void remove(Key key)	*remove* `key` *from set*
boolean contains(Key key)	*is* `key` *in the set?*
int size()	*number of elements in set*

The full SET API.

Our graph data type.

public class Graph		
	Graph()	*create an empty graph*
	Graph(String filename, String delimiter)	*create graph from a file*
void	addEdge(String v, String w)	*add edge v-w*
int	V()	*number of vertices*
int	E()	*number of edges*
Iterable<String>	vertices()	*vertices in the graph*
Iterable<String>	adjacentTo(String v)	*neighbors of v*
int	degree(String v)	*number of neighbors of v*
boolean	hasVertex(String v)	*is v a vertex in the graph?*
boolean	hasEdge(String v, String w)	*is v-w an edge in the graph?*

The full Graph API.

Compile-time and run-time errors. Here's a list of errors compiled by Mordechai Ben-Ari. It includes a list of common error message and typical mistakes that give rise to them.

Last modified on October 30, 2019.