

Basics

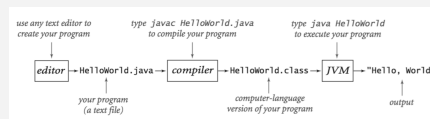
Hello, World

```

text file named HelloWorld.java
    |
    v
public class HelloWorld
{
    public static void main(String[] args)
    {
        // Prints "Hello, World" in the terminal window.
        System.out.print("Hello, World");
    }
}
    
```

Annotations in the code above:
 - `name` points to `HelloWorld`
 - `main() method` points to `public static void main(String[] args)`
 - `statements` points to the block of code inside the `main` method
 - `body` points to the entire class definition

Editing, Compiling, and executing



Built in Datatypes

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"

Integers

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

Integer Operations

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



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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	+	-	*	/

Floating Point Numbers Operations

expression	value
3.141 + 2.0	5.141
3.141 - 2.0	1.141
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

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 as replaced by bs
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

String operations

```
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 is"
b.startsWith("the")	boolean	true
a.indexOf("is")	int	4
a.concat(c)	String	"now is the"
b.replace("t", "p")	String	"The Time"
a.split(" ")	String[]	{ "now", "is" }
b.equals(c)	boolean	false

Commands to Split a String Into Separate Parts

```
Scanner scan = new Scanner(System.in);

Sys tem.out.println ("What is your date of birth? (Format: dd mm yyyy) ");

String dateBirthDay = scan.nextLine();

String[] parts = dateBirthDay.split(" ");

// Storing users birthday data
int day = Integer.parseInt(parts[0]);
```



Commands to Split a String Into Separate Parts (cont)

```
> int month = Integer.parseInt(parts[1]);
int year = Integer.parseInt(parts[2]);
// Obtaining today's date:
int currentDay = LocalDate.now().getDayOfMonth();
int currentMonth = LocalDate.now().getMonthValue();
int currentYear = LocalDate.now().getYear();
```

Math Library

expression	expression type	expression value
<code>double abs(double a)</code>		<i>absolute value of a</i>
<code>double max(double a, double b)</code>		<i>maximum of a and b</i>
<code>double min(double a, double b)</code>		<i>minimum of a and b</i>
<code>double sin(double theta)</code>		<i>sine of theta</i>
<code>double cos(double theta)</code>		<i>cosine of theta</i>
<code>double tan(double theta)</code>		<i>tangent of theta</i>
<code>double toRadians(double degrees)</code>		<i>convert angle from degrees to radians</i>
<code>double toDegrees(double radians)</code>		<i>convert angle from radians to degrees</i>
<code>double exp(double a)</code>		<i>exponential (e^a)</i>
<code>double log(double a)</code>		<i>natural log (log_e a, or ln a)</i>
<code>double pow(double a, double b)</code>		<i>raise a to the bth power (a^b)</i>
<code>long round(double a)</code>		<i>round a to the nearest integer</i>
<code>double random()</code>		<i>random number in [0, 1)</i>
<code>double sqrt(double a)</code>		<i>square root of a</i>
<code>double E</code>		<i>value of e (constant)</i>
<code>double PI</code>		<i>value of π (constant)</i>

Type Conversions

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

Parsing Command-Line Arguments

<code>int Integer.parseInt(String s)</code>	<i>convert s to an int value</i>
<code>double Double.parseDouble(String s)</code>	<i>convert s to a double value</i>
<code>long Long.parseLong(String s)</code>	<i>convert s to a long value</i>

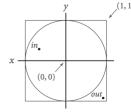
Switch statement

```
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;
}
```



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);
```



Example Functions

absolute value of an int value	<pre>public static int abs(int x) { if (x < 0) return -x; else return x; }</pre>
absolute value of a double value	<pre>public static double abs(double x) { if (x < 0.0) return -x; else return x; }</pre>
primality test	<pre>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; }</pre>
hypotenuse of a right triangle	<pre>public static double hypotenuse(double a, double b) { return Math.sqrt(a*a + b*b); }</pre>
harmonic number	<pre>public static double harmonic(int n) { double sum = 0.0; for (int i = 1; i <= n; i++) sum += 1.0 / i; return sum; }</pre>
uniform random integer in [0, n)	<pre>public static int uniform(int n) { return (int) (Math.random() * n); }</pre>
draw a triangle	<pre>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); }</pre>

Typical Array Problems

create an array with random values	<pre>double[] a = new double[n]; for (int i = 0; i < n; i++) a[i] = Math.random();</pre>
print the array values, one per line	<pre>for (int i = 0; i < n; i++) System.out.println(a[i]);</pre>
find the maximum of the array values	<pre>double max = Double.NEGATIVE_INFINITY; for (int i = 0; i < n; i++) if (a[i] > max) max = a[i];</pre>
compute the average of the array values	<pre>double sum = 0.0; for (int i = 0; i < n; i++) sum += a[i]; double average = sum / n;</pre>
reverse the values within an array	<pre>for (int i = 0; i < n/2; i++) { double temp = a[i]; a[i] = a[n-1-i]; a[n-1-i] = temp; }</pre>
copy sequence of values to another array	<pre>double[] b = new double[n]; for (int i = 0; i < n; i++) b[i] = a[i];</pre>



Formatted Output

<code>%d</code>	Integer in base 10 ("decimal")	12345
<code>%,d</code>	Integer with comma separators	12,345
<code>%08d</code>	Padded with zeros, at least 8 digits wide	00012345
<code>%f</code>	Floating-point number	6.789000
<code>%.2f</code>	Rounded to 2 decimal places	6.79
<code>%s</code>	String of characters	"Hello"
<code>%x</code>	Integer in base 16 ("hexadecimal")	bc614e

Table 3.1: Example format specifiers

Memory Usage of Data Types

type	bytes
boolean	1
byte	1
char	2
int	4
float	4
long	8
double	8

Command Line Input from File

```

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);
    }
}
    
```

The diagram illustrates the execution of the `AddInts` class. It shows a command line argument `% java AddInts 4` being passed to the program. This input is read from the standard input stream, which provides the values `144`, `233`, `377`, and `1024`. The program then calculates the sum of these values and outputs `Sum is 1778` to the standard output stream.

Classes Overview

```

public class Charge
{
    private final double rx, ry;
    private final double q;

    public Charge(double x0, double y0, double q0)
    { rx = x0; ry = y0; q = q0; }

    public double potentialAt(double x, double y)
    {
        double k = 8.99e09;
        double dx = x - rx;
        double dy = y - ry;
        return k * q / Math.sqrt(dx*dx + dy*dy);
    }

    public String toString()
    { return q + " at " + "(" + rx + ", " + ry + ")"; }

    public static void main(String[] args)
    {
        double x = Double.parseDouble(args[0]);
        double y = Double.parseDouble(args[1]);
        Charge c1 = new Charge(0.51, 0.63, 21.3);
        Charge c2 = new Charge(0.13, 0.94, 81.9);
        double v1 = c1.potentialAt(x, y);
        double v2 = c2.potentialAt(x, y);
        StdOut.printf("%.2e\n", (v1 + v2));
    }
}
    
```

The diagram shows the structure of the `Charge` class. It includes instance variables (`rx`, `ry`, `q`), a constructor, instance methods (`potentialAt`, `toString`), and a test client (`main`). The test client creates two `Charge` objects and uses their `potentialAt` method to calculate the sum of their potentials at a given point.

Method to Read a Matrix From a File

```

public static double[][] readMatrix(String filename)
    throws java.io.FileNotFoundException {
    File file = new File(filename);
    Scanner input = new Scanner(file);

    int rows = input.nextInt();
    
```



Method to Read a Matrix From a File (cont)

```
> int columns = input.nextInt();

double[][] matrix = new double[rows][columns];

for (int i=0;i<rows;i++){
    for (int j=0;j<columns;j++){
        matrix [i][j]= input.nextDouble();
    }
}

input.close();
return matrix;
}
```

Two first Integers in a file defines the size of a matrix n x m.

Tutorial Content

Random Arrays

```
// returns an array of length n containing random integer values
public static int[] random Int Arr ay(int n){
    Random random = new Random();
    int[] array = new int[n];
    for(int i=0; i < n; i++){
        arr ay[i] = random.ne xtI nt();
    }
    return array;
}

// returns an array of length n containing random integer values
// in the interval [lb,ub]
public static int[] random Int Arr ay(int n, int lb, int ub){
    Random random = new Random();
    int[] array = new int[n];
    for(int i=0; i < n; i++){
        arr ay[i] = random.ne xtI nt( ub- lb+1) + lb;
    }
}
```



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Random Arrays (cont)

```
> return array;
}

// returns an array of length n containing random double values
public static double[] randomDoubleArray(int n){
    Random random = new Random();
    double[] array = new double[n];
    for(int i=0; i < n; i++){
        array[i] = random.nextDouble();
    }
    return array;
}

// returns an array of length n containing random double values
// in the interval [lb,ub]
public static double[] randomDoubleArray(int n, int lb, int ub){
    Random random = new Random();
    double[] array = new double[n];
    for(int i=0; i < n; i++){
        array[i] = random.nextDouble(ub-lb+1) + lb;
    }
    return array;
}
}
```

Read Double Array.

```
public static double[] readArray(String filename)
    throws java.io.FileNotFoundException{
    File file = new File(filename);
    Scanner input = new Scanner(file);

    int n = input.nextInt();

    double[] doubleArray = new double[n];

    for (int i=0;i<n;i++){
        doubleArray[i] = input.nextDouble();
    }
}
```



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Read Double Array. (cont)

```
> input.close();

return doubleArray;
}
```

To read other type array, we substitute the "doubles" with int or int[] or nextInt()

Digit Sum Method

```
public static int totalDigitSum(int n) {
    int number OfD igits = (Strin g.v alu eOf (n) ).l eng th();
    int sum = 0;
    Sys tem.ou t.p rin t("The total digit sum");
    whi le( num ber OfD igits != 0) {
        sum = sum + (n%10);
        n = n/10;
        num ber OfD igi ts--;
    }
    return sum;
}
```

Print Prime Factors

```
public static void printPrimeFactors(int n) {
    if (n <= 1) {
        Sys tem.ou t.p rin t("No prime factor s");
        return;
    }
    for (int i = 2; i <= n; i++) {
        while (n % i == 0) {
            Sys tem.ou t.p rint(i + " ");
            n /= i;
        }
    }
}
```

Method to print the prime factors of a given number



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Method to compute Factorials (n!)

```
public static int[] computeFactorials(int n) {
    int[] factorials = new int[n];
    factorials[0] = 1;

    for (int i = 1; i < n; i++) {
        factorials[i] = factorials[i - 1] * (i + 1);
    }

    return factorials;
}
```

Method Simulating Dice Rolling N times

```
public static double expectedValue (int numberOfTrials){

    double sum = 0;

    for(int i = 1; i <= number OfT rials; i++){
        sum = sum + (int) (Math.random() * 6) +1;
    }

    return sum/nu mbe rOf Trials;
}
```

Program that computes the expected value of rolling a six sided dice. Input parameter is the number of trials

Method for Standard Deviation

```
// Method that computes standard deviation of an array
public static double getStandardDeviation( double[] array) {
    double sum = 0;
    double mean = getMean(array);
    for (double i : array) {
        double temp = (i - mean) * (i - mean);
        sum += temp;
    }
    double standardDeviation = sum/array.length;
    standardDeviation = Math.sqrt (standardDeviation);
    return standardDeviation;
}
```



Greatest Common Divisor & Least Common Multiple

```
// GCD
public static int getGcd(int n, int m) {
    while(m%n != 0) {
        int temp = m%n;
        m = n;
        n = temp;
    }
    return n;
}

// LCM
public static int lcm(int a, int b) {
    int gcd = gcd(a, b);
    return (a / gcd) * b;
}
```

Determining the Season

```
/* Program that asks the user for a date and returns in which season this date falls.
// method calculating determining the season, given the month and day
public int getSeason(int day, int month) {
    // Formula to translate everything on one 'scale'
    int combinedValue = month*100 + day;
    if (combinedValue >= 321 & combinedValue <= 620) {
        this.season = 1;
    }
    else if (combinedValue >= 621 & combinedValue <= 920) {
        this.season = 2;
    }
    else if (combinedValue >= 921 & combinedValue <= 1220) {
        this.season = 3;
    }
    else {
        this.season = 0;
    }
}
```



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Determining the Season (cont)

```
> }  
    return this.season;  
}
```

Sorting Algorithms

Commands for Random Numbers

```
double random1 = Math.random();  
  
    System.out.println("A random value between 0 and 1: " + random1);  
  
    double random2 = Math.random()*100;  
  
    System.out.println("A random double value between 0 and 100: " + random2);  
  
    int random3 = (int) (Math.random()* 100);  
  
    System.out.println("A random integer value between 0 and 99: " + random3);
```

Binary Search Method

```
public static boolean find(int[] array, int number){  
  
    int low = 0;  
    int high = array.length-1;  
  
    while (low+1 < high) {  
        int mid = (high + low) /2;  
  
        if (array [mid] == number){  
            return true;  
        }  
        else if (array [mid] < number){  
            low = mid;  
        }  
        else {  
            high = mid;  
        }  
    }  
  
    return ((array [low] == number) || (array [high] == number));  
}
```

Random Sorted Int Array

```
public static int[] randomSortedIntArray(int n, int startValue, int maxIncrement){
    Random random = new Random();
    int[] array = new int[n];
    array[0] = startValue;
    for(int i=1; i < n; i++){
        array[i] = array[i-1] + random.nextInt(maxIncrement);
    }
    return array;
}
```

Random Sorted Int Array (Basis for Binary Search)

Insertion Sort Algorithm

```
public static void sort(int[] a) {
    int n = a.length; // Get the length of the input
                                array 'a'.

    for (int i = 1; i < n; i++) {
        for (int j = i; j > 0; j--) {
            // This loop iterates from the current
            // position 'i' towards the beginning
            // of the array.
            if (a[j-1] > a[j]) {
                // If the element at the previous
                // position is greater than the
                // current element,
                // we need to swap them to sort
                // the array in ascending order.
                swap(a, j-1, j);
            } else {
                // If the element at the previous
                // position is not greater than the
                // current element,
                // it means the array is sorted
            }
        }
    }
}
```



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Insertion Sort Algorithm (cont)

```
>         up to this point, so we break out of the
         loop.
         break;
     }
 }
 }
 }
 }
public static void swap(int[] arr, int index1, int index2) {
    // This function swaps two elements
    in the array 'arr' at the given indices 'index1'
    and 'index2'.
    int temp = arr[index1];
    arr[index1] = arr[index2];
    arr[index2] = temp;
}
```

Random Array in Interval

```
public static int[] randomArray(int n){
    int[] array = new int[n];

    for(int i=0; i<n ;i++){
        array [i] = (int) ( Math.r and om( ) *1000 - 500);
    }
    return array;
}
```

random array length n, interval int between [-500;500]

Insertion Sort of an Object w.r.t. String/Int

```
// Insertion Sort Algorithm based on First Name
public static void sortFirst Name(PersonNew[] person List) {
    for(int i = 1; i < person Lis t.l ength; i++) {
        Per sonNew curren tPerson = person Lis t[i];
        int j = i - 1;
```



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```
> boolean flag = true;
// We will compare current person's name with other ones
while(j >= 0 && flag) {
    String currentName = currentPerson.getFirstName();
    String testName = personList[j].getFirstName();
    // Checking which name is shorter:
    int minimum = Math.min(currentName.length(), testName.length());
    int k = 0;
    // Now we will check which name is "smaller" based on ascii:
    while(k < minimum) {
        char letterCurrent = currentName.charAt(k);
        char letterTest = testName.charAt(k);
        // Current Name is larger than other
        if(letterCurrent < letterTest) {
            personList[j+1] = personList[j];
            j--;
            break;
        }
        // Current Name is already smaller
        else if(letterTest < letterCurrent) {
            flag = false;
            break;
        }
        // They have the same characters, thus we continue going through each string
        else {
            k++;
        }
        // We reach the end of smaller name, meaning that they have the same name:
        if(k == minimum) {
            personList[j+1] = personList[j];
            j--;
        }
    }
}
```



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```
>     }
    }
}
// Inserting in its correct position.
personList[j+1] = currentPerson;
}
}
// Insertion Sort Algorithm based on Height
public static void sortHeight(PersonNew[] personList) {
    for(int i = 1; i < personList.length; i++) {
        PersonNew currentPerson = personList[i];
        int j = i-1;
        while((j >= 0) && currentPerson.isTaller(personList[j])) {
            personList[j+1] = personList[j];
            j--;
        }
        personList[j+1] = currentPerson;
    }
}
```

Objects

Constructor Method for Point / Line

```
// constructor for a line through points p and q
// sets slope and intercept to Double.NaN for vertical lines
public Line(Point p, Point q) {
    // vertical line:
    if (p.getX() == q.getX()) {
        this.intercept = Double.NaN;
        this.slope = Double.NaN;
    }
    // otherwise we compute the slope (y2 - y1) / (x2 - x1)
```



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Constructor Method for Point / Line (cont)

```
> // and intercept from  $y = mx + c$ , using one of the points
else {
    this.slope = (q.getY() - p.getX()) / (q.getX() - p.getX());
    this.intercept = p.getY() - this.slope * p.getX();
}
}
```

This Constructor computes the equation of the line, given two points

Few Methods for Object Date

```
// method that returns true if this date is before the date given by the argument
public boolean isBefore(Date date) {
    if (this.year <= date.year) {
        if (this.month <= date.month) {
            if (this.day <= date.day) {
                return true;
            }
            return false;
        }
        return false;
    }
    return false;
}

// method that increments this date by one day
public void increment() {
    // Array storing days per month
    int[] daysPerMonth = {0, 31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31};
    // Figure out if its leap year, to change daysPerMonth[2] = 29.
    if (isLeapYear()) {
        daysPerMonth[2] = 29;
    }
    // Check if its last day of the month
    if (this.day == daysPerMonth[this.month]) {
```



Few Methods for Object Date (cont)

```
> this.day = 1;
// Check if its new year:
if(this.month == 12) {
    this.month = 1;
    year++;
}
else {
    month++;
}
}
else {
    day++;
}
}
// method that returns true if the year of this date is a leap year
private boolean isLeapYear() {
    return (this.year % 4 == 0 && this.year % 100 != 0) || (this.year % 400 == 0);
}
}
```

We store dd/mm/yyyy in the Object Date. Constructor method is not shown here.

Methods For Rational Numbers (Object Rational)

```
// add rational f2 to this rational and return the result.
public Rational add(Rational f2) {
    if( this.denominator == f2.getDenominator() ) {
        int numerator = this.numerator + f2.getNumerator();
        return new Rational( numerator, this.denominator);
    }
    else {
        // we find the new denominator:
        int newDenominator = findLCM(this.denominator, f2.getDenominator());
        int numerator = (this.numerator * (newDenominator / this.denominator)) +
(f2.getNumerator() * (newDenominator / f2.getDenominator()));
        return new Rational( numerator, newDenominator);
    }
}
```



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Methods For Rational Numbers (Object Rational) (cont)

```
> }
}
// compute the reciprocal of this Rational and return the result
public Rational reciprocal() {
    return new Rational(this.denominator, this.numerator);
}
// divide this Rational by Rational f2 and return the result
public Rational divide(Rational f2) {
    Rational reciprocalf2 = f2.reciprocal();
    int newNum = this.numerator * reciprocalf2.getNumerator();
    int newDen = this.denominator * reciprocalf2.getDenominator();
    return new Rational(newNum, newDen);
}
```

Reciprocal: x/y becomes y/x .

Runtime Exercises

Run Times

description	order of growth	example	benchmark
constant	1	<code>count++</code>	constant (decrement on integer)
logarithmic	$\log n$	for (int i = n; i > 0; i /= 2) count++	divide in half (bit in binary representation)
linear	n	for (int i = 0; i < n; i++) if (a[i] == 0) count++	single loop (check each element)
discontinuous	$n \log n$	[see mergeSort (Section 4.2.6)]	divide-and-conquer (mergeSort)
quadratic	n^2	for (int i = 0; i < n; i++) for (int j = 0; j < n; j++) if (a[i] + a[j] == 0) count++	double nested loop (check all pairs)
cubic	n^3	for (int i = 0; i < n; i++) for (int j = 0; j < n; j++) for (int k = 0; k < n; k++) if (a[i] + a[j] + a[k] == 0) count++	triple nested loop (check all triplets)
exponential	2^n	[see GenYield (Section 3.3.3)]	exhaustive search (check all subsets)

Knapsack Problem

```
public static int knapsackAlgorithm(int n, int[] profits, int[] volumes, int V) {
    // Create a 2D array 'P' to store the maximum profit for different combinations
    of items and volumes.
    int[][] P = new int[n + 1][V + 1];
    // Initialize the first row (no items) with zeros, as no profit can be gained.
    for (int v = 0; v <= V; v++) {
```



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Knapsack Problem (cont)

```

> P[0][v] = 0;
}
// Loop through the items (i) and the available volume (v).
for (int i = 1; i <= n; i++) {
    for (int v = 0; v <= V; v++) {
        // Check if the volume of the current item can fit in the
available volume (v).
        if (volumes[i - 1] <= v) {
            // If it can fit, calculate the maximum profit for two options:
            // 1. Including the current item and subtracting its volume
from the available volume.
            // 2. Excluding the current item.
            P[i][v] = Math.max(profits[i - 1] + P[i - 1]
[v - volumes[i - 1]], P[i - 1][v]);
        } else {
            // If the current item cannot fit, take the maximum profit
from the previous row.
            P[i][v] = P[i - 1][v];
        }
    }
}
// The final element of the 'P' array (bottom-right) contains the
maximum profit achievable with the given constraints.
return P[n][V];
}

public static int[] generateRandomArray(int size, int min, int max) {
    // Create an array of the specified size.
    int[] array = new int[size];
    Random rand = new Random();

    // Fill the array with random integers in the range [min, max].
    for (int i = 0; i < size; i++) {

```



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Knapsack Problem (cont)

```
> array[i] = rand.nextInt(max - min + 1) + min;
}

// Return the generated array.
return array;
}
```

Magic Square Problem

```
public static boolean isMagic(int[][] matrix) {
    return (hasUnequalSums(matrix) && hasEqualSums(matrix));
}

// Method that checks if all rows, columns and
two diagonals (right & left) have equal sums:
public static boolean hasEqualSums(int[][] matrix) {
    // Variable to store target sum:
    int targetSum = 0;
    // Target sum = sum of first row
    for(int i = 0; i < matrix.length; i++) {
        targetSum += matrix[0][i];
    }
    int leftDiagonal = 0;
    int rightDiagonal = 0;
    for(int j = 0; j < matrix.length; j++) {
        int sumColumn = 0;
        int sumRow = 0;
        for(int k = 0; k < matrix[0].length; k++) {
            sumRow += matrix[j][k];
            sumColumn += matrix[k][j];
            // Check if we are on the left diagonal:
            if(j == k) {
                leftDiagonal += matrix[j][k];
            }
        }
        // Check if we are on the right diagonal:
```



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Magic Square Problem (cont)

```

>     if(j+k == matrix.length - 1) {
        rightDiagonal += matrix[j][k];
    }
    }
    // Check if the sum is equal to our target one:
    if (sumRow != targetSum || sumColumn != targetSum) {
        return false;
    }
}
// Check if diagonal sums are = target
if(rightDiagonal != targetSum || leftDiagonal != targetSum) {
    return false;
}
return true;
}
// Method that checks whether matrix contains
only unique numbers from 1 to n*n.
public static boolean hasUniqueNumbers(int[][] matrix) {
    /*
    We know that there will be numbers from 1 to n*n.
    We create boolean array of size n*n which
will help to flag not unique numbers.
    Default array element value = false.
    */
    int n = matrix.length;
    boolean[] seenNumber = new boolean[n*n];
    int arrayIndex = 0;
    for(int i = 0; i < matrix.length; i++) {
        for(int j = 0; j < matrix[0].length; j++) {
            int number = matrix[i][j];
            // We check whether the number has

```



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Magic Square Problem (cont)

```
> already been flagged && whether 1 <= number <= n*n
    if(!seenNumber[number - 1] && number >= 1 && number <= (n*n)) {
        // Number is being flagged:
        seenNumber[number - 1] = true;
    }
    else {
        return false;
    }
}
}
return true;
}

public static int [][] rotate(int [][] matrix){
    int n = matrix.length;
    int m = matrix[0].length;
    // Create a new matrix to store the rotated elements
    int [][] transpose = new int[n][m];
    for(int i=0;i<n;i++){
        for(int j=0;j<n;j++){
            transpose[i][j]=matrix[j][i];
        }
    }
    int [][] rotated = new int[n][m];
    int x = n-1;
    for (int k = 0; k < n; k++) {
        rotated[k] = transpose[x];
        x--;
    }
    return rotated;
}
```



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Data Structures

Stack Data Type

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

Integer Stack Class

```
import java.util.*;

public class IntegerStack {
    private int size; // size of the stack
    private Node first; // top of stack
    // helper linked list class
    private class Node {
        private int value;
        private Node next;
    }
    // Constructor for an empty stack
    public IntegerStack() {
        this.first = null;
        this.size = 0;
    }
    // Returns true if this stack is empty.
    public boolean isEmpty() {
        return first == null;
    }
    // returns the size of this stack
    public int size() {
        return this.size;
    }
    // adds number to the top of the stack
    public void push(int number) {
        Node oldfirst = first;
```



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Intger Stack Class (cont)

```
>    first = new Node();
    first.value = number;
    first.next = oldfirst;
    size++;
}
public String toString() {
    IntegerStack aux = new IntegerStack();
    String stackString = new String();
    while (!this.isEmpty()) {
        int x = this.pop();
        stackString += x + " ";
        aux.push(x);
    }
    while (!aux.isEmpty()) {
        this.push(aux.pop());
    }
    stackString += "\n";
    return stackString;
}
/**
 * Removes and returns the item most recently added to this stack.
 */
public int pop() {
    // if (isEmpty()) throw new NoSuchElementException("Stack underflow");
    int number = first.value; // save item to return
    first = first.next; // delete first node
    size--;
    return number; // return the saved item
}
public void absoluteValue() {
    IntegerStack aux = new IntegerStack();
```



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Integer Stack Class (cont)

```
> while (!this.isEmpty()) {
    aux.push(Math.abs(this.pop()));
}
// put auxiliary stack back on both stacks
while (!aux.isEmpty()) {
    this.push(aux.pop());
}
}
// Method that checks if two stacks are exactly the same
public boolean isEqual(IntegerStack secondStack) {
    IntegerStack aux = new IntegerStack();
    boolean flag = true;
    // Stacks are of a different size.
    if(this.size != secondStack.size) {
        flag = false;
        return flag;
    }
    // Checking whether the two are the same
    while(!this.isEmpty() && !secondStack.isEmpty()) {
        int thisNumber = this.pop();
        int secondNumber = secondStack.pop();
        if(!(thisNumber == secondNumber)) {
            // Immediately push back the numbers on top:
            this.push(thisNumber);
            secondStack.push(secondNumber);
            flag = false;
            break;
        }
        aux.push(thisNumber);
    }
    // Restoring both stacks:
```



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Integer Stack Class (cont)

```
> while (!aux.isEmpty()) {
    int number = aux.pop();
    this.push(number);
    secondStack.push(number);
}
return flag;
}

// Method that reverses the order of the stack:
public void reverse() {
    // empty stack:
    if(this.isEmpty()) {
        System.out.println("Empty stack was provided.");
        return;
    }
    Queue<Integer> tempQ = new Queue<Integer>();
    // Putting all elements from stack to queue data structure
    while(!this.isEmpty()) {
        tempQ.enqueue(this.pop());
    }
    // Putting everything from queue to stack, to get reverse order
    while(!tempQ.isEmpty()) {
        this.push(tempQ.dequeue());
    }
}

// Fills stack with -1 and 1 randomly
public void fillStackRandom() {
    Random randomNumber = new Random();
    for(int i = 0; i < 100; i++) {
        int number = randomNumber.nextInt(2) == 0 ? 1 : -1;
        this.push(number);
    }
}
```



Integer Stack Class (cont)

```
> }
}
```

Queue Data Type

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

Queue Class

```
import java.util.Iterator;
import java.util.NoSuchElementException;
public class Queue<Item> implements Iterable<Item> {
    private int n; // number of elements on queue
    private Node first; // beginning of queue
    private Node last; // end of queue
    // helper linked list class
    private class Node {
        private Item item;
        private Node next;
    }
    // Initializes an empty queue.
    public Queue() {
        first = null;
        last = null;
        n = 0;
    }
    // Returns true if this queue is empty.
    public boolean isEmpty() {
        return first == null;
    }
    // Returns the number of items in this queue.
    public int length() {
```



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Queue Class (cont)

```
>     return n;
    }
// Returns the item least recently added to this queue.
public Item peek() {
    if (isEmpty()) throw new NoSuchElementException("Queue underflow");
    return first.item;
}
// Add the item to the queue.
public void enqueue(Item item) {
    Node oldlast = last;
    last = new Node();
    last.item = item;
    last.next = null;
    if (isEmpty()) first = last;
    else oldlast.next = last;
    n++;
}
// Removes and returns the item on this queue that was least recently added.
public Item dequeue() {
    if (isEmpty()) throw new NoSuchElementException("Queue underflow");
    Item item = first.item;
    first = first.next;
    n--;
    if (isEmpty()) last = null; // to avoid loitering
    return item;
}
// Returns a string representation of this queue.
public String toString() {
    StringBuilder s = new StringBuilder();
    for (Item item : this) {
        s.append(item);
```



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Queue Class (cont)

```
>     s.append(' ');
    }
    return s.toString();
}
/*
method to remove all negative integers from a queue.
it checks the last element of the queue, if its not negative
element goes to the back of the queue,
*/
public void removeNegatives() {
    int sizeQ = this.size();
    for(int i = 0; i < sizeQ; i++) {
        Item lastElement = this.dequeue();
        if((int) lastElement >= 0) {
            // it's positive, thus put the item back of the queue
            this.enqueue(lastElement);
        }
    }
}
// Returns an iterator that iterates over the items in this queue in FIFO order.
public Iterator<Item> iterator() {
    return new ListIterator();
}
// an iterator, doesn't implement remove() since it's optional
private class ListIterator implements Iterator<Item> {
    private Node current = first;
    public boolean hasNext() { return current != null; }
    public void remove() { throw new UnsupportedOperationException(); }
    public Item next() {
        if (!hasNext()) throw new NoSuchElementException();
        Item item = current.item;

```



Queue Class (cont)

```
>     current = current.next;
      return item;
    }
  }
}
```

ArrayList data structure Commands

```
ArrayList<Integer> list = new ArrayList<>();
// Add an element to the list
list.add(x);
// Copy list
list.clone();
// Element at the index i
list.get(i);
// Is element present in the list, returns T/F
list.contains(x);
// Returns the index of the item x
list.indexOf(x);
// Returns the size of list
list.size();
// Check if list is empty, return T/F
list.isEmpty();
// Replace an element x at index i with element y
list.set(i, y);
// ArrayList into array:
size of array is same as the ArrayList
int[] arr = new int[list.size()];
// Convert ArrayList into an array
list.toArray(arr);
// Convert ArrayList into String, basically outputs the list
list.toString();
```



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Advanced Tutorial Content

Call Center Exercise

```
import java.util.ArrayList;
public class CallCenter{
    // Constants for the simulation
    private final int number OfEmployees = 10;
    private final int number OfTime Periods = 480;
    private final int maxNumber OfCustomers = 5;
    private final int maxServiceTime = 5;
    // Variables to store simulation results
    private int totalWaitTime = 0;
    private int totalNumber OfServedCustomers = 0;
    private int finalQueueLength = 0;
    public static void main (String[] args){
        // Create an instance of the CallCenter class
        CallCenter myCallCenter = new CallCenter();
        // Run the call center simulation
        myCallCenter.runSimulation();
        // Print the simulation statistics
        myCallCenter.printStatistics();
    }
    public void printStatistics(){
        // Printing the simulation statistics.
        System.out.println ("The call center simulation was run with " + number OfEmployees + "
employ ees.");
        System.out.println ("Be tween 9am and 5pm " + (final QueueLength + totalNumber OfServedCustomers) + " customers have called ");
        System.out.println ("The average wait time was "+ (1.0*totalWaitTime / totalNumber OfServedCustomers) + " minute s.");
        System.out.println ("Number of unserved customers: " + finalQueueLength);
    }
    // runs the simulation as described in the assignment
    public void runSimulation(){
        // We begin with an empty queue
        Queue< Customer> myQ = new Queue<>();
```



Call Center Exercise (cont)

```
> // List of Employees
ArrayList<Employee> listEmployees = assignEmployee(numberOfEmployees);
// We go through the day:
for(int currentTime = 0; currentTime < numberOfTimePeriods; currentTime++) {
    // Each minute new customers "join the queue"
    randomArrivals(maxServiceTime, maxNumberOfCustomers, currentTime, myQ);
    // For each employee we assign a new customer if possible:
    for(Employee employee : listEmployees) {
        // There are customers in queue and employee is available:
        if(employee.getAvailableAt() <= currentTime && !myQ.isEmpty()) {
            Customer servedCustomer = myQ.dequeue();
            // Adding how long customer waited to the total & recording him as served one.
            totalWaitTime += (currentTime - servedCustomer.getArrivalTime());
            totalNumberOfServedCustomers++;
            int timeRequired = servedCustomer.getServiceTime();
            // Change employees available time
            employee.setAvailableAt(currentTime + timeRequired);
        }
    }
}
// After 8 hours, number of people not served:
finalQueueLength = myQ.size();
}
}
// helper method to fill employee list
public ArrayList<Employee> assignEmployee(int n) {
    ArrayList<Employee> list = new ArrayList<>();
    for(int i = 0; i < n; i++) {
        // Create Employee objects and add them to the list
        Employee emp = new Employee(i);
        list.add(emp);
    }
}
```



Call Center Exercise (cont)

```
> return list;
}
// helper method for simulating callers arriving to the queue:
public void randomArrivals(int maxServiceTime, int maxNumberOfCustomers, int timeOfArrival, Queue myQ) {
    int numberOfArrivals = (int) (Math.random()*maxNumberOfCustomers + 1);
    for(int i = 0; i < numberOfArrivals; i++){
        // each customer will have different service time
        int serviceTime = (int) (Math.random()*maxServiceTime + 1);
        Customer customer = new Customer(timeOfArrival, serviceTime);
        // add customer to the end of the queue
        myQ.enqueue(customer);
    }
}
}
```

Employee Class For Call Center

```
public class Employee{

    private final int id;
    private int availableAt;

    // constructs an Employee with an id and initial available time at 0
    public Employee (int id){
        this.id = id;
        this.availableAt = 0;
    }

    // returns the id of this employee
    public int getId(){
        return this.id;
    }

    // returns the time at which an employee is available again
    public int getAvailableAt(){
        return this.availableAt;
    }
}
```



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Employee Class For Call Center (cont)

```
> // sets the time at which an employee is available again
public void setAvailableAt(int time){
    this.availableAt = time;
}
}
```

Customer Class For Call Center

```
public class Customer{
    private final int arriva lTime;
    private final int servic eTime;

    // constructs a Customer with arrival time a and duration d
    public Customer (int arriva lTime, int servic eTime){
        thi s.a rri valTime = arriva lTime;
        thi s.s erv iceTime = servic eTime;
    }

    // returns the arrival time of this customer
    public int getArr iva lTi me(){
        return this.a rri val Time;
    }

    // returns the service time of this customer
    public int getSer vic eTi me(){
        return this.s erv ice Time;
    }
}
```

Elevator Problem

```
// method to solve the number of elevators problem:
public static int number OfE lev ato rs( Arr ayL ist <Pe rso n> person List) {
    Arr ayL ist <In teg er> elevators = new ArrayL ist <>();
    // Initial " bin " is empty:
    ele vat ors.ad d(0);
    int elevat orCount = 1;
```



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Elevator Problem (cont)

```
> for(Person person:personList) {
    // flag will tell whether the person fitted in the current elevator:
    boolean flag = false;
    int weight = person.getWeight();
    // Check if person fits in one of the existing bins (elevators):
    for (int i = 0; i < elevatorCount; i++) {
        int currentElevatorWeight = elevators.get(i);
        // Person fits in the elevator
        if((currentElevatorWeight + weight) <= 450) {
            elevators.set(i, weight + currentElevatorWeight);
            flag = true;
        }
    }
    // Other elevators didn't have space, we open new "bin":
    if(!flag) {
        elevators.add(weight);
        elevatorCount++;
    }
}
return elevatorCount;
}

// helper method to sort the list descending or ascending by weight. char d for descending and a for ascending.
public static void insertionSortWeight(ArrayList<Person> personList, char order){
    int n = personList.size();
    for (int i = 1; i < n; i++) {
        Person key = personList.get(i);
        int j = i - 1;
        // Compare weights for sorting
        if (order == 'a' || order == 'A') { // Ascending order
            while (j >= 0 && personList.get(j).getWeight() > key.getWeight()) {
                personList.set(j + 1, personList.get(j));
            }
        }
    }
}
```



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Elevator Problem (cont)

```
>     j--;
    }
} else if (order == 'd' || order == 'D') { // Descending order
    while (j >= 0 && personList.get(j).getWeight() < key.getWeight()) {
        personList.set(j + 1, personList.get(j));
        j--;
    }
}
personList.set(j + 1, key);
}
}
```

Game Of Stacks

```
public int runGameStrategy1(){
    // The first step of the game is to create
the needed random stack
    Integer gameStack = Integer.parseInt(RandomStack());
    // From here we go to the procedures of the game itself
    // generate two player scores and ID's
    int aliceID = 1;
    int bobID = -1;
    int aliceScore = 0;
    int bobScore = 0;
    // Move tracker that checks whos turn it is
    int move = 0;
    // The game starts
    while (!gameStack.isEmpty()){
        // First we check whos turn it is since both
players only take 1 turn every time due to the strategy
        if (move % 2 == 0) {
            // Alice starts and ONLY keeps every 1
            if (gameStack.pop() == aliceID){
```



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Game Of Stacks (cont)

```
>         aliceScore += 1;
        }
    } else {
        // Bob starts and ONLY keeps every -1
        if (gameStack.pop() == bobID){
            bobScore += 1;
        }
    }
    move += 1;
}
if (aliceScore > bobScore) {
    return 1;
} else if (aliceScore == bobScore) {
    return 0;
} else {
    return -1;
}
}
public int runGameStrategy2() {
    // The first step of the game is to create
the needed random stack
    IntegerStack gameStack = IntegerStack.createRandomStack();
    int aliceScore = 0;
    int bobScore = 0;
    // Move tracker that checks whos turn it is
    int currentPlayer = 0;
    // The game starts
    while (!gameStack.isEmpty()) {
        int top = gameStack.pop();
        if( currentPlayer%2 == 0 ) {
            if (top == 1) {
```



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Game Of Stacks (cont)

```
>
    int consecOnes = 1;
    if(gameStack.isEmpty()) break;
    int next = gameStack.pop();
    if (next == 1) {
        consecOnes++;
    } else consecOnes = 0;
    aliceScore += consecOnes;
}
} else if (top == -1) {
    bobScore += 1;
}
currentPlayer++;
}
if (aliceScore > bobScore) {
    return 1;
} else if (aliceScore == bobScore) {
    return 0;
} else {
    return -1;
}
}
```

Average BMI method

```
// Method that calculates average BMI index per age group:
public static void averageBMI(ArrayList<Person> personList) {
    int[] ageGroup = {20,30,40,50,60,70};
    // 20-29 group corresponds to index 0, 30-39 to 1 and so on
    int[] groupCount = new int[ageGroup.length];
    double[] groupSumBMI = new double[ageGroup.length];
    for(int i = 0; i < personList.size(); i++) {
        Person currentPerson = personList.get(i);
        // age/10 - 2, will give correct index( group number) of the object for its place
        // in the arrays.
    }
}
```



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Average BMI method (cont)

```
>     int personsGroup = currentPerson.getAge()/10 - 2;
      groupCount[personsGroup]++;
      groupSumBMI[personsGroup] += currentPerson.getBMI();
    }
```



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