

Topic 21

arrays - part 1

"Should array indices start at 0 or 1? My compromise of 0.5 was rejected without, I thought, proper consideration. "

- *Stan Kelly-Bootle*



Can we solve this problem?

- ▶ Consider the following program (input underlined):

How many days' temperatures? 7

Day 1's high temp: 45

Day 2's high temp: 44

Day 3's high temp: 39

Day 4's high temp: 48

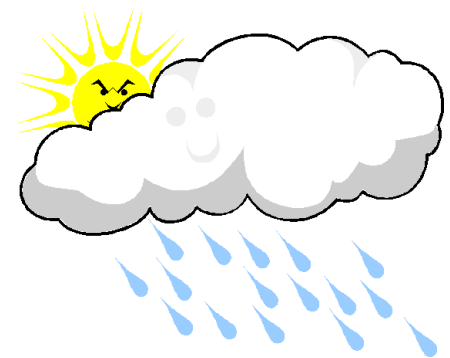
Day 5's high temp: 37

Day 6's high temp: 46

Day 7's high temp: 53

Average temp = 44.6

4 days were above average.

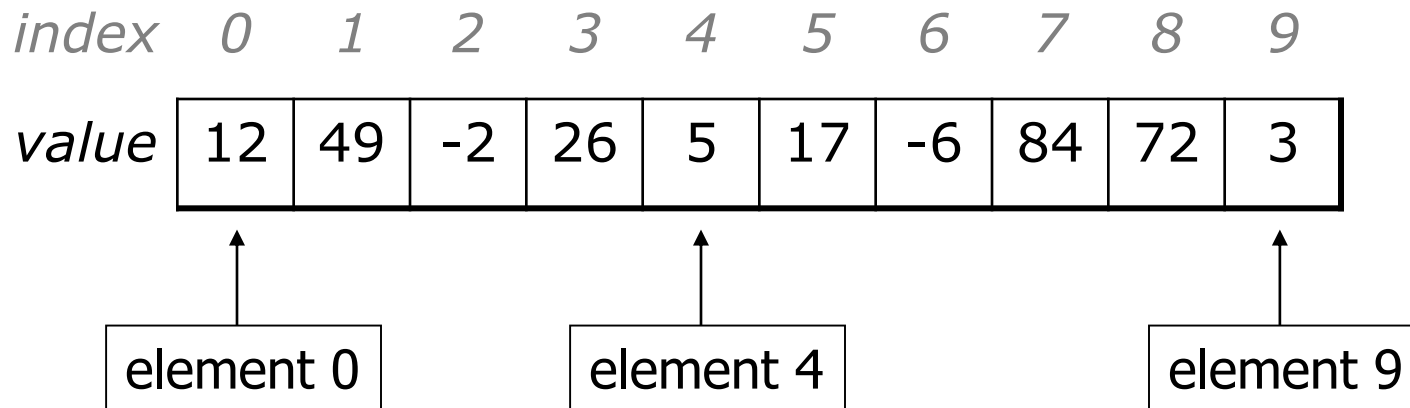


Why the problem is hard

- ▶ We need each input value twice:
 - to compute the average (a cumulative sum)
 - to count how many were above average
- ▶ We could read each value into a variable...
but we:
 - don't know how many days are needed until the program runs
 - don't know how many variables to declare
- ▶ **We need a way to declare many variables in one step.**

Arrays

- ▶ **array**: object that stores many values of the same type.
 - **element**: One value in an array.
 - **index**: A **0-based integer** to access an element from an array.



Array declaration

<type> [] **<name>** = new **<type>** [**<length>**] ;

– Example:

```
int[] numbers = new int[10];
```

index 0 1 2 3 4 5 6 7 8 9

<i>value</i>	0	0	0	0	0	0	0	0	0	0
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Array declaration, cont.

- ▶ The length can be any non-negative integer expression.

```
int x = 2 * 3 + 1;
```

```
int[] data = new int[x % 5 + 2];
```

- ▶ Each element initially gets a "zero-equivalent" value.

Type	Default value
int	0
double	0.0
boolean	false
String or other object	null (means, "no object")

Accessing elements

<name> [**<index>**] // access

<name> [**<index>**] = **<value>**; // modify

– Example:

```
numbers[0] = 27;
```

```
numbers[3] = -6;
```

```
System.out.println(numbers[0]);
```

```
if (numbers[3] < 0) {
```

```
    System.out.println("Element 3 is negative.");
```

```
}
```

index 0 1 2 3 4 5 6 7 8 9

<i>value</i>	27	0	0	-6	0	0	0	0	0	0
--------------	-----------	---	---	-----------	---	---	---	---	---	---

Arrays of other types

```
double[] results = new double[5];  
results[2] = 3.4;  
results[4] = -0.5;
```

<i>index</i>	0	1	2	3	4
<i>value</i>	0.0	0.0	3.4	0.0	-0.5

```
boolean[] tests = new boolean[6];  
tests[3] = true;
```

<i>index</i>	0	1	2	3	4	5
<i>value</i>	false	false	false	true	false	false

Out-of-bounds

- ▶ Legal indexes: between **0** and the **array's length - 1**.
 - Reading or writing any index outside this range will throw an `ArrayIndexOutOfBoundsException`.

- ▶ Example:

```
int[] data = new int[10];  
System.out.println(data[0]);           // okay  
System.out.println(data[9]);           // okay  
System.out.println(data[-1]);         // exception  
System.out.println(data[10]);        // exception
```

<i>index</i>	0	1	2	3	4	5	6	7	8	9
<i>value</i>	0	0	0	0	0	0	0	0	0	0

Accessing array elements

```
int[] numbers = new int[8];  
numbers[1] = 3;  
numbers[4] = 99;  
numbers[6] = 2;  
int x = numbers[1];  
numbers[x] = 42;  
numbers[numbers[6]] = 11; // use numbers[6] as index
```

x

3

	<i>index</i>	0	1	2	3	4	5	6	7
<i>numbers</i>	<i>value</i>	0	3	11	42	99	0	2	0

Clicker 1

▶ What is output by the following code?

```
String[] names = new String[5];  
names[1] = "Olivia";  
names[3] = "Isabelle";  
System.out.print(names[0].length());
```

- A. no output due to null pointer exception
- B. no output due to array index out of bounds exception
- C. no output due to a compile error (code can't run)
- D. 0
- E. 6

Arrays and `for` loops

- ▶ It is common to use `for` loops to access array elements.

```
for (int i = 0; i < 8; i++) {  
    System.out.print(numbers[i] + " ");  
}  
System.out.println(); // output: 0 3 11 42 99 0 2 0
```

- ▶ Sometimes we assign each element a value in a loop.

```
for (int i = 0; i < 8; i++) {  
    numbers[i] = 2 * i;  
}
```

<i>index</i>	0	1	2	3	4	5	6	7
<i>value</i>	0	2	4	6	8	10	12	14

The length field

- ▶ An array's `length` field stores its number of elements.

<name>.length

```
for (int i = 0; i < numbers.length; i++) {  
    System.out.print(numbers[i] + " ");  
}
```

// output: 0 2 4 6 8 10 12 14

- It does not use parentheses like a String's `.length()`.

- ▶ What expressions refer to:
 - The last element of any array?
 - The middle element?

Weather question

- ▶ Use an array to solve the weather problem:

How many days' temperatures? 7

Day 1's high temp: 45

Day 2's high temp: 44

Day 3's high temp: 39

Day 4's high temp: 48

Day 5's high temp: 37

Day 6's high temp: 46

Day 7's high temp: 53

Average temp = 44.6

4 days were above average.

Weather answer

```
// Reads temperatures from the user, computes average and # days above average.
import java.util.*;

public class Weather {
    public static void main(String[] args) {
        Scanner console = new Scanner(System.in);
        System.out.print("How many days' temperatures? ");
        int days = console.nextInt();

        int[] temps = new int[days];           // array to store days' temperatures
        int sum = 0;

        for (int i = 0; i < temps.length; i++) {// read/store each day's temp
            System.out.print("Day " + (i + 1) + "'s high temp: ");
            temps[i] = console.nextInt();
            sum += temps[i];
        }
        double average = (double) sum / days;

        int count = 0;                          // see if each day is above average
        for (int i = 0; i < temps.length; i++) {
            if (temps[i] > average) {
                count++;
            }
        }

        // report results
        System.out.printf("Average temp = %.1f\n", average);
        System.out.println(count + " days above average");
    }
}
```

Quick array initialization

`<type>[] <name> = { <value>, <value>, ... <value> } ;`

– Example:

```
int[] numbers = {12, 49, -2, 26, 5, 17, -6};
```

<i>index</i>	0	1	2	3	4	5	6
<i>value</i>	12	49	-2	26	5	17	-6

- Useful when you know what the array's elements will be
- The compiler determines the length by counting the values

"Array mystery" problem

- ▶ **traversal:** An examination of each element of an array.
- ▶ What element values are stored in the following array?

```
int[] a = {1, 7, 5, 6, 4, 14, 11};  
for (int i = 0; i < a.length - 1; i++) {  
    if (a[i] > a[i + 1]) {  
        a[i + 1] = a[i + 1] * 2;  
    }  
}
```

<i>index</i>	0	1	2	3	4	5	6
<i>value</i>	1	7	10	12	8	14	22

Limitations of arrays

- ▶ You cannot resize an existing array:

```
int[] a = new int[4];  
a.length = 10;           // error
```

- ▶ You cannot compare arrays with `==` or `equals`:

```
int[] a1 = {42, -7, 1, 15};  
int[] a2 = {42, -7, 1, 15};  
if (a1 == a2) { ... }           // false!  
if (a1.equals(a2)) { ... }     // false!
```

- ▶ An array does not know how to print itself:

```
int[] a1 = {42, -7, 1, 15};  
System.out.println(a1);           // [I@98f8c4]
```

The Arrays class

- ▶ Class `Arrays` in package `java.util` has useful static methods for manipulating arrays:

Method name	Description
<code>binarySearch(<array>, <value>)</code>	returns the index of the given value in a <i>sorted</i> array (or <code>< 0</code> if not found)
<code>copyOf(<array>, <length>)</code>	returns a new copy of an array
<code>equals(<array1>, <array2>)</code>	returns <code>true</code> if the two arrays contain same elements in the same order
<code>fill(<array>, <value>)</code>	sets every element to the given value
<code>sort(<array>)</code>	arranges the elements into sorted order
<code>toString(<array>)</code>	returns a string representing the array, such as <code>"[10, 30, -25, 17]"</code>

- ▶ Syntax:

`Arrays.<methodName> (<parameters>)`

Arrays.toString

- ▶ `Arrays.toString` accepts an array as a parameter and returns a `String` representation of its elements.

```
int[] e = {0, 2, 4, 6, 8};  
e[1] = e[3] + e[4];  
System.out.println("e is " + Arrays.toString(e));
```

Output:

```
e is [0, 14, 4, 6, 8]
```

– **Must** `import java.util.Arrays;`

Weather question 2

- ▶ Modify the weather program to print the following output:

```
How many days' temperatures? 7
```

```
Day 1's high temp: 45
```

```
Day 2's high temp: 44
```

```
Day 3's high temp: 39
```

```
Day 4's high temp: 48
```

```
Day 5's high temp: 37
```

```
Day 6's high temp: 46
```

```
Day 7's high temp: 53
```

```
Average temp = 44.6
```

```
4 days were above average.
```

```
Temperatures: [45, 44, 39, 48, 37, 46, 53]
```

```
Two coldest days: 37, 39
```

```
Two hottest days: 53, 48
```

Weather answer 2

```
// Reads temperatures from the user, computes average and # days above average.
import java.util.*;

public class Weather2 {
    public static void main(String[] args) {
        ...
        int[] temps = new int[days];           // array to store days' temperatures
        ...   (same as Weather program)

        // report results
        System.out.printf("Average temp = %.1f\n", average);
        System.out.println(count + " days above average");

        System.out.println("Temperatures: " + Arrays.toString(temps));
        Arrays.sort(temps);
        System.out.println("Two coldest days: " + temps[0] + ", " + temps[1]);
        System.out.println("Two hottest days: " + temps[temps.length - 1] +
            ", " + temps[temps.length - 2]);
    }
}
```