Chapter 3
Lecture 7: Return values, Math, and double

reading: 3.2, 2.1 - 2.2
I'll need to know your requirements before I start to design the software.

First of all, what are you trying to accomplish?

I'm trying to make you design my software.

I mean what are you trying to accomplish with the software?

I won't know what I can accomplish until you tell me what the software can do.

Try to get this concept through your thick skull: the software can do whatever I design it to do!

Can you design it to tell you my requirements?
## Java's `Math` class

<table>
<thead>
<tr>
<th>Method name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>Math.abs(value)</code></td>
<td>absolute value</td>
</tr>
<tr>
<td><code>Math.ceil(value)</code></td>
<td>rounds up</td>
</tr>
<tr>
<td><code>Math.floor(value)</code></td>
<td>rounds down</td>
</tr>
<tr>
<td><code>Math.log10(value)</code></td>
<td>logarithm, base 10</td>
</tr>
<tr>
<td><code>Math.max(value1, value2)</code></td>
<td>larger of two values</td>
</tr>
<tr>
<td><code>Math.min(value1, value2)</code></td>
<td>smaller of two values</td>
</tr>
<tr>
<td><code>Math.pow(base, exp)</code></td>
<td><code>base</code> to the <code>exp</code> power</td>
</tr>
<tr>
<td><code>Math.random()</code></td>
<td>random double between 0 and 1</td>
</tr>
<tr>
<td><code>Math.round(value)</code></td>
<td>nearest whole number</td>
</tr>
<tr>
<td><code>Math.sqrt(value)</code></td>
<td>square root</td>
</tr>
<tr>
<td><code>Math.sin(value)</code></td>
<td>sine/cosine/tangent of an angle in radians</td>
</tr>
<tr>
<td><code>Math.cos(value)</code></td>
<td></td>
</tr>
<tr>
<td><code>Math.tan(value)</code></td>
<td></td>
</tr>
<tr>
<td><code>Math.toDegrees(value)</code></td>
<td>convert degrees to radians</td>
</tr>
<tr>
<td><code>Math.toRadians(value)</code></td>
<td>radians and back</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Constant</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>Math.E</code></td>
<td>2.7182818...</td>
</tr>
<tr>
<td><code>Math.PI</code></td>
<td>3.1415926...</td>
</tr>
</tbody>
</table>
No output?

- Simply calling these methods produces no visible result.
  - `Math.pow(3, 4); // no output`

- Math method calls use a Java feature called *return values* that cause them to be treated as expressions.

- The program runs the method, computes the answer, and then "replaces" the call with its computed result value.
  - `Math.pow(3, 4); // no output`
  - `81.0; // no output`

- To see the result, we must print it or store it in a variable.
  - `double result = Math.pow(3, 4);`
  - `System.out.println(result); // 81.0`
Return

• **return**: To send out a value as the result of a method.
  • Return values send information *out* from a method to its caller.
  • A call to the method can be used as part of an expression.
  • (Compare to parameters which send values *into* a method)

\[
\text{main} \quad \xrightarrow{-42} \quad \text{Math.abs}(-42) \xrightarrow{42} \quad 2.71 \quad \xrightarrow{3} \quad \text{Math.round}(2.71)
\]
Math questions

- Evaluate the following expressions:
  - `Math.abs(-1.23)`
  - `Math.pow(3, 2)`
  - `Math.pow(10, -2)`
  - `Math.sqrt(121.0) - Math.sqrt(256.0)`
  - `Math.ceil(6.022) + Math.floor(15.9994)`
  - `Math.abs(Math.min(-3, -5))`

- `Math.max` and `Math.min` can be used to bound numbers. Consider an `int` variable named `age`.
  - What statement would replace negative ages with 0?
  - What statement would cap the maximum age to 40?
Why return and not print?

- It might seem more useful for the Math methods to print their results rather than returning them. Why don't they?

  - Answer: Returning is more flexible than printing.
    - We can compute several things before printing:
      ```java
double pow1 = Math.pow(3, 4);
double pow2 = Math.pow(10, 6);
System.out.println("Powers are " + pow1 + " and " + pow2);
```
    - We can combine the results of many computations:
      ```java
double k = 13 * Math.pow(3, 4) + 5 - Math.sqrt(17.8);
```
Returning a value

```java
public static type name(parameters) {
    statements;
    ...
    return expression;
}
```

- When Java reaches a return statement:
  - it evaluates the expression
  - it substitutes the return value in place of the call
  - it goes back to the caller and continues after the method call
Return examples

// Converts degrees Fahrenheit to Celsius.
public static double fToC(double degreesF) {
    double degreesC = 5.0 / 9.0 * (degreesF - 32);
    return degreesC;
}

// Computes triangle hypotenuse length given its side lengths.
public static double hypotenuse(int a, int b) {
    double c = Math.sqrt(a * a + b * b);
    return c;
}

• You can shorten the examples by returning an expression:

    public static double fToC(double degreesF) {
        return 5.0 / 9.0 * (degreesF - 32);
    }
Common error: Not storing

- Many students incorrectly think that a `return` statement sends a variable's name back to the calling method.

```java
public static void main(String[] args) {
    slope(0, 0, 6, 3);
    System.out.println("The slope is " + result); // ERROR: // cannot find symbol: result
}

public static double slope(int x1, int x2, int y1, int y2) {
    double dy = y2 - y1;
    double dx = x2 - x1;
    double result = dy / dx;
    return result;
}
```
Fixing the common error

- Returning sends the variable's *value* back. Store the returned value into a variable or use it in an expression.

```java
public static void main(String[] args) {
    double s = slope(0, 0, 6, 3);
    System.out.println("The slope is " + s);
}

public static double slope(int x1, int x2, int y1, int y2) {
    double dy = y2 - y1;
    double dx = x2 - x1;
    double result = dy / dx;
    return result;
}
```
Quirks of real numbers

- Some `Math` methods return `double` or other non-int types.
  ```java
  int x = Math.pow(10, 3);  // ERROR: incompat. types
  ```

- Some `double` values print poorly (too many digits).
  ```java
  double result = 1.0 / 3.0;
  System.out.println(result);  // 0.33333333333333333
  ```

- The computer represents `doubles` in an imprecise way.
  ```java
  System.out.println(0.1 + 0.2);
  ```
  - Instead of 0.3, the output is 0.30000000000000004
Type casting

- **type cast**: A conversion from one type to another.
  - To promote an `int` into a `double` to get exact division from `/`
  - To truncate a `double` from a real number to an integer

- Syntax:
  ```
  (type) expression
  ```

Examples:
```java
double result = (double) 19 / 5;  // 3.8
int result2 = (int) result;       // 3
int x = (int) Math.pow(10, 3);   // 1000
```
More about type casting

• Type casting has high precedence and only casts the item immediately next to it.
  • `double x = (double) 1 + 1 / 2;` // 1.0
  • `double y = 1 + (double) 1 / 2;` // 1.5

• You can use parentheses to force evaluation order.
  • `double average = (double) (a + b + c) / 3;`

• A conversion to `double` can be achieved in other ways.
  • `double average = 1.0 * (a + b + c) / 3;`
Exercise

- In physics, the displacement of a moving body represents its change in position over time while accelerating.
  - Given initial velocity \( v_0 \) in m/s, acceleration \( a \) in m/s\(^2\), and elapsed time \( t \) in s, the displacement of the body is:
    - Displacement = \( v_0 t + \frac{1}{2} a t^2 \)

- Write a method `displacement` that accepts \( v_0 \), \( a \), and \( t \) and computes and returns the change in position.
  - example: `displacement(3.0, 4.0, 5.0)` returns 65.0
public static double displacement(double v0, double a, double t) {
    double d = v0 * t + 0.5 * a * Math.pow(t, 2);
    return d;
}
Exercise

• If you drop two balls, which will hit the ground first?
  • Ball 1: height of 600m, initial velocity = 25 m/sec downward
  • Ball 2: height of 500m, initial velocity = 15 m/sec downward

• Write a program that determines how long each ball takes to hit the ground (and draws each ball falling).

• Total time is based on the force of gravity on each ball.
  • Acceleration due to gravity \( \approx 9.81 \text{ m/s}^2 \), downward
  • Displacement = \( v_0 t + \frac{1}{2} a t^2 \)
Ball solution

// Simulates the dropping of two balls from various heights.
import java.awt.*;

public class Balls {
    public static void main(String[] args) {
        DrawingPanel panel = new DrawingPanel(600, 600);
        Graphics g = panel.getGraphics();

        int ball1x = 100, ball1y = 0, v01 = 25;
        int ball2x = 200, ball2y = 100, v02 = 15;

        // draw the balls at each time increment
        for (double t = 0; t <= 10.0; t = t + 0.1) {
            double disp1 = displacement(v01, t, 9.81);
            g.fillOval(ball1x, ball1y + (int) disp1, 10, 10);
            double disp2 = displacement(v02, t, 9.81);
            g.fillOval(ball2x, ball2y + (int) disp2, 10, 10);

            panel.sleep(50);  // pause for 50 ms
            panel.clear();
        }
    }
}