Building Java Programs

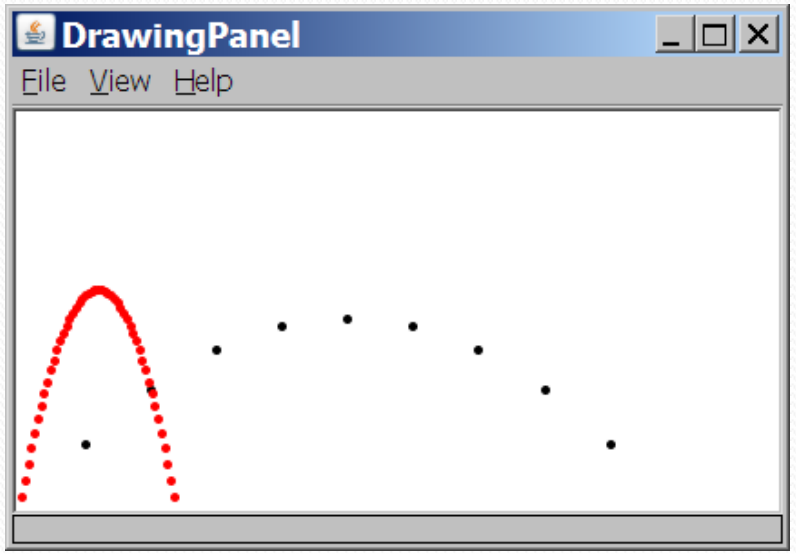
Chapter 3
Lecture 3-2: Return; `double`; `System.out.printf`

reading: 3.2, 3.5, 4.4
videos: Ch. 3 #2, 4

Projectile problem

- Write a program that displays (as text and graphics) the paths of projectiles thrown at various velocities and angles.
  - Projectile #1: velocity = 60, angle = 50°, steps = 10
  - Projectile #2: velocity = 50, angle = 80°, steps = 50

```
step         x         y     time
   0      0.00      0.00     0.00
   1     36.14     38.76     0.94
   2     72.28     68.91     1.87
   3    108.42     90.45     2.81
   4    144.56    103.37     3.75
   5    180.70    107.67     4.69
   6    216.84    103.37     5.62
   7    252.98     90.45     6.56
   8    289.12     68.91     7.50
   9    325.26     38.76     8.43
  10    361.40      0.00     9.37

step         x         y     time
   0      0.00      0.00     0.00
   1      1.74      9.69     0.20
   2      3.49     18.98     0.40
  ...
```



Return Values

reading: 3.2

self-check: #7-11

exercises: #4-6

videos: Ch. 3 #2

Java's `Math` class

Method name	Description
`Math.abs(`*value*`)`	absolute value
`Math.round(`*value*`)`	nearest whole number
`Math.ceil(`*value*`)`	rounds up
`Math.floor(`*value*`)`	rounds down
`Math.log10(`*value*`)`	logarithm, base 10
`Math.max(`*value1*`, `*value2*`)`	larger of two values
`Math.min(`*value1*`, `*value2*`)`	smaller of two values
`Math.pow(`*base*`, `*exp*`)`	*base* to the *exp* power
`Math.sqrt(`*value*`)`	square root

`Math.sin(`*value*`)`
`Math.cos(`*value*`)`
`Math.tan(`*value*`)`
	sine/cosine/tangent of an angle in radians

`Math.toDegrees(`*value*`)` `Math.toRadians(`*value*`)`	convert degrees to radians and back
`Math.random()`	random `double` between 0 and 1

Constant	Description
`Math.E`	2.7182818...
`Math.PI`	3.1415926...

Calling `Math` methods

```
Math.methodName(parameters)
```

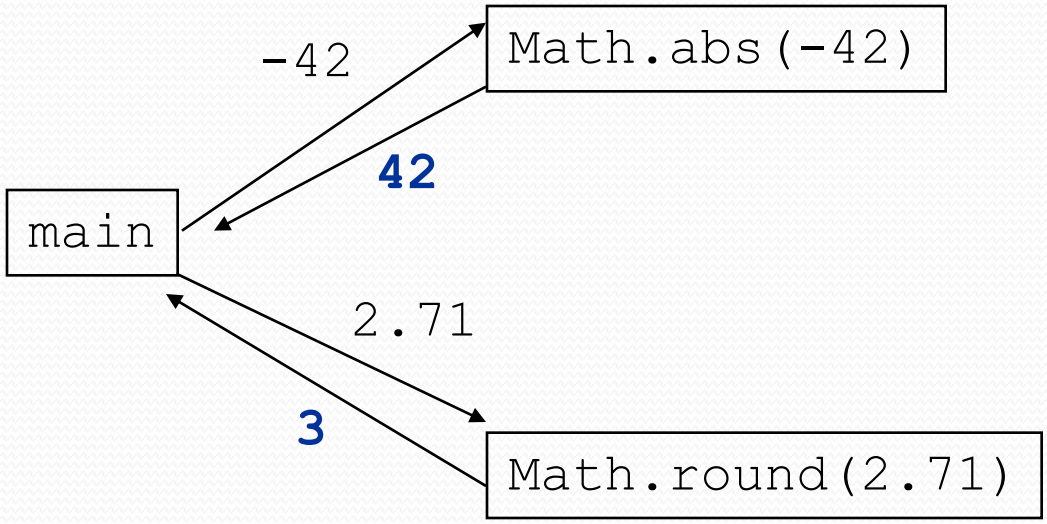
- Examples:

```
double squareRoot = Math.sqrt(121.0);
System.out.println(squareRoot);              // 11.0

int absoluteValue = Math.abs(-50);
System.out.println(absoluteValue);           // 50

System.out.println(Math.min(3, 7) + 2);      // 5
```

- The `Math` methods do not print to the console.
  - Each method produces ("returns") a numeric result.
  - The results are used as expressions (printed, stored, etc.).

Return

- **return**: To send out a value as the result of a method.
  - The opposite of a parameter:
    - Parameters send information *in* from the caller to the method.
    - Return values send information *out* from a method to its caller.



`Math` Mini-Exercises #1

- Evaluate the following expressions:
  - `Math.abs(-1.23)`
  - `Math.pow(3, 2)`
  - `Math.pow(10, -2)`
  - `Math.sqrt(25.0) - Math.sqrt(9.0)`

Method name	**Description**
`Math.abs(`*value*`)`	absolute value
`Math.pow(`*base*`, `*exp*`)`	*base* to the *exp* power
`Math.sqrt(`*value*`)`	square root

`Math` Mini-Exercises - Solutions

- Evaluate the following expressions:
  - `Math.abs(-1.23)  =>  1.23`
  - `Math.pow(3, 2)  =>  9.0`
  - `Math.pow(10, -2)  =>  0.01`
  - `Math.sqrt(25.0) - Math.sqrt(9.0)  => 2.0`

Method name	**Description**
`Math.abs(`*value*`)`	absolute value
`Math.pow(`*base*`, `*exp*`)`	*base* to the *exp* power
`Math.sqrt(`*value*`)`	square root

`Math` Mini-Exercises #2

- `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?

Method name	**Description**
`Math.max(`*value1*`, `*value2*`)`	larger of two values
`Math.min(`*value1*`, `*value2*`)`	smaller of two values

`Math` Mini-Exercises #2 - Solutions

- `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?

    ```
    age = Math.max(age,0);
    ```

  - What statement would cap the maximum age to 40?

    ```
    age = Math.min(age,40);
    ```

Returning a value

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

- Example:

```
// Returns the slope of the line between the given points.
public static double slope(int x1, int y1, int x2, int y2) {
    double dy = y2 - y1;
    double dx = x2 - x1;
    return dy / dx;
}
```

Return examples

```
// Converts 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.

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

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

- Instead, returning sends the variable's *value* back.
  - The returned value must be stored into a variable or used in an expression to be useful to the caller.

```
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.

```
int x = Math.pow(10, 3);   // ERROR: incompat. types
```

- Some `double` values print poorly (too many digits).

```
double result = 1.0 / 3.0;
System.out.println(result);     // 0.3333333333333
```

- The computer represents `double`s in an imprecise way.

```
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 real-number division from the `/` operator
  - To truncate a `double` from a real number to an integer

- Syntax:

  (**type**) **expression**

  Examples:

```
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`
  - `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;`

System.out.printf

an advanced command for printing formatted text

```
System.out.printf("format string", parameters);
```

- A format string contains *placeholders* to insert parameters into it:
  - `%d` an integer
  - `%f` a real number
  - `%s` a string

  - Example:

```
int x = 3;
int y = 2;
System.out.printf("(%d, %d)\n", x, y);   // (3, 2)
```

System.out.printf cont'd

- A placeholder can specify the parameter's *width* or *precision*:
  - `%8d` an integer, 8 characters wide, right-aligned
  - `%-8d` an integer, 8 characters wide, left-aligned
  - `%.4f` a real number, 4 characters after decimal
  - `%6.2f` a real number, 6 characters wide, 2 after decimal

  - Examples:

```
int age = 45;
double gpa = 1.2345678;

System.out.printf("%-8d %4f\n", age, gpa);
System.out.printf("%8.3f %.1f %.5f", gpa, gpa, gpa);
```

  - Output:

```
45       1.23
   1.234 1.2 1.23457
```

System.out.printf Mini-exercises

- Write a statement that prints **`"pi = "`** followed by pi to 6 decimal places (use `Math.PI` to obtain the value of pi)

- Write a statement that prints a double `x` to 6 decimal places and that includes 10 characters total (including leading spaces as needed)

- Cheat sheet:
  A placeholder can specify the parameter's *width* or *precision*:
  - `%8d` an integer, 8 characters wide, right-aligned
  - `%-8d` an integer, 8 characters wide, left-aligned
  - `%.4f` a real number, 4 characters after decimal
  - `%6.2f` a real number, 6 characters wide, 2 after decimal

System.out.printf
Mini-exercises - solutions

- Write a statement that prints **"pi = "** followed by pi to 6 decimal places (use `Math.PI` to obtain the value of pi)

```
System.out.printf("pi =  %.6f", Math.PI);
```

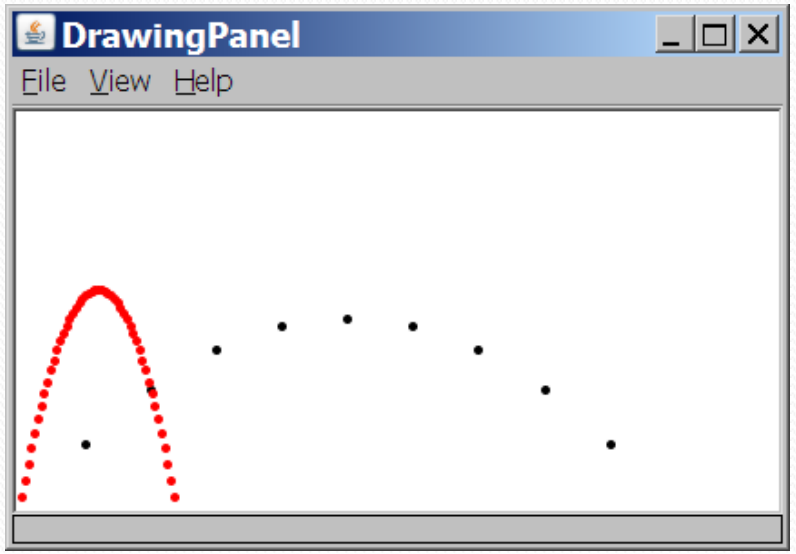
- Write a statement that prints a double `x` to 6 decimal places and that includes 10 characters total (including leading spaces as needed)

```
System.out.printf(%10.6f", x);
```

Projectile problem revisited

- *Recall:* Display (as text and graphics) the paths of projectiles thrown at various velocities and angles.
  - Projectile #1: velocity = 60, angle = 50°, steps = 10
  - Projectile #2: velocity = 50, angle = 80°, steps = 50

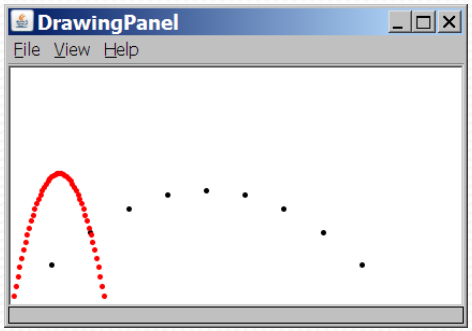
```
step         x         y     time
   0      0.00      0.00     0.00
   1     36.14     38.76     0.94
   2     72.28     68.91     1.87
   3    108.42     90.45     2.81
   4    144.56    103.37     3.75
   5    180.70    107.67     4.69
   6    216.84    103.37     5.62
   7    252.98     90.45     6.56
   8    289.12     68.91     7.50
   9    325.26     38.76     8.43
  10    361.40      0.00     9.37

step         x         y     time
   0      0.00      0.00     0.00
   1      1.74      9.69     0.20
   2      3.49     18.98     0.40
  ...
```



Time observations

- We are given the number of "steps" of time to display.
  - We must figure out how long it takes the projectile to hit the ground, then divide this time into the # of steps requested.

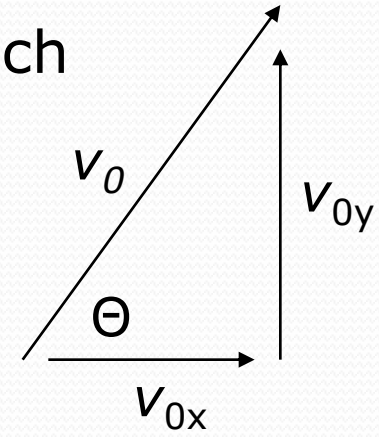
```
step        x         y     time
   0     0.00      0.00     0.00
   1    36.14     38.76     0.94
   2    72.28     68.91     1.87
  ...
  10   361.40      0.00     9.37
```



- Total time is based on the force of gravity on the projectile.
  - Force of gravity (g) ☜ 9.81 m/s^2, downward
  - The projectile has an initial upward velocity, which is fought by gravity until the projectile reaches its peak, then it falls.

Velocity and acceleration

- The projectile has a given initial velocity v_0, which can be divided into x and y components.
  - $v_{0x} = v_0 \cos \Theta$
  - $v_{0y} = v_0 \sin \Theta$
    - Example: If v_0=13 and Θ=60°, v_{0x}=12 and v_{0y}=5.



- The velocity v_t of a moving body at time t, given initial velocity v_0 and acceleration a, can be expressed as:
  - $v_t = v_0 + a\,t$
- In our case, because of symmetry, at the end time t the projectile is falling exactly as fast as it was first going up.
  - $v_{ty} = -v_{0y}$
    $-v_{0y} = v_{0y} + a\,t$
    $\boldsymbol{t = -2\,v_{0y} / a}$

X/Y position, displacement

- Based on the previous, we can now display *x* and *time*.
  - $x_t = v_x t$ since there is no force in the x direction.

```
step        x        y     time
   0     0.00     ????     0.00
   1    36.14     ????     0.94
   2    72.28     ????     1.87
  ...
  10   361.40     ????     9.37
```

- To display the y, we need to compute the projectile's *displacement* in y direction at each time increment.
  - $y_t = v_{0y} t + \frac{1}{2} a t^2$
  - Since this formula is complicated, let's make it into a method.

Projectile solution

```
// This program computes and draws the trajectory of a projectile.

import java.awt.*;

public class Projectile {
    // constant for Earth's gravity acceleration in meters/second^2
    public static final double ACCELERATION = -9.81;

    public static void main(String[] args) {
        DrawingPanel panel = new DrawingPanel(420, 250);
        Graphics g = panel.getGraphics();

        //       v0  angle  steps
        table(g,  60,  50,  10);

        g.setColor(Color.RED);
        table(g,  50,  80,  50);
    }

    // returns the displacement for a body under acceleration
    public static double displacement(double v0, double t, double a) {
        return v0 * t + 0.5 * a * t * t;
    }

    ...
```

Projectile solution

```
    ...
    // prints a table showing the trajectory of an object given
    // its initial velocity v and angle and number of steps
    public static void table(Graphics g, double v0,
                             double angle, int steps) {
        double v0x = v0 * Math.cos(Math.toRadians(angle));
        double v0y = v0 * Math.sin(Math.toRadians(angle));
        double totalTime = -2.0 * v0y / ACCELERATION;
        double dt = totalTime / steps;

        System.out.println("    step       x       y    time");
        for (int i = 0; i <= steps; i++) {
            double time = i * dt;
            double x = i * v0x * dt;
            double y = displacement(v0y, time, ACCELERATION);
            System.out.printf("%8d%8.2f%8.2f%8.2f\n", i, x, y, time);
            g.fillOval((int) x, (int) (250 - y), 5, 5);
        }
    }
}
```