Building Java Programs

Chapter 3

Lecture 3-1: Parameters

reading: 3.1

Redundant recipes

- Recipe for baking **20** cookies:
  - Mix the following ingredients in a bowl:
    - **4** cups flour
    - **1** cup butter
    - **1** cup sugar
    - **2** eggs
    - **1** bag chocolate chips ...
  - Place on sheet and Bake for about 10 minutes.

- Recipe for baking **40** cookies:
  - Mix the following ingredients in a bowl:
    - **8** cups flour
    - **2** cups butter
    - **2** cups sugar
    - **4** eggs
    - **2** bags chocolate chips ...
  - Place on sheet and Bake for about 10 minutes.

Parameterized recipe

- Recipe for baking **20** cookies:
  - Mix the following ingredients in a bowl:
    - **4** cups flour
    - **1** cup sugar
    - **2** eggs
    - **...**
- Recipe for baking **N** cookies:
  - Mix the following ingredients in a bowl:
    - **N/5** cups flour
    - **N/20** cups butter
    - **N/20** cups sugar
    - **N/10** eggs
    - **N/20** bags chocolate chips ...
  - Place on sheet and Bake for about 10 minutes.
- **parameter**: A value that distinguishes similar tasks.

Redundant figures

- Consider the task of printing the following lines/boxes:

```
**********

*******

**************************************

**********
*        *
**********

*****
*   *
*   *
*****
```

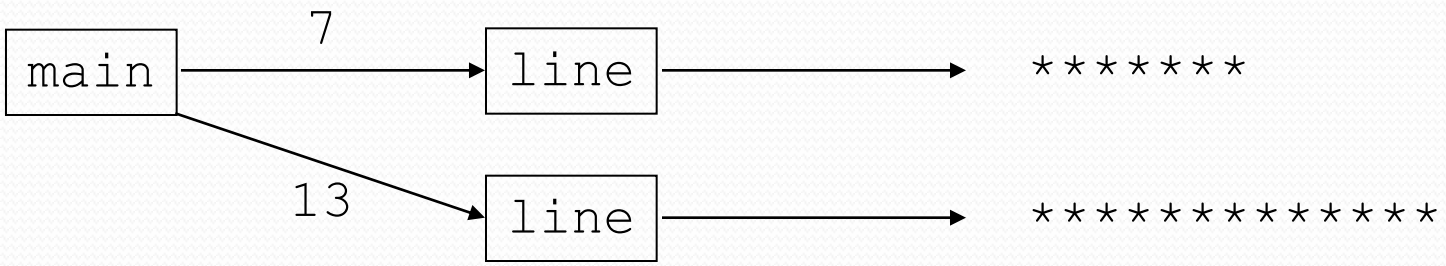
A redundant solution

```
public class Stars1 {
    public static void main(String[] args) {
        lineOf13();
        lineOf7();
        lineOf35();
        box10x3();
        box5x4();
    }

    public static void lineOf13() {
        for (int i = 1; i <= 13; i++) {
            System.out.print("*");
        }
        System.out.println();
    }

    public static void lineOf7() {
        for (int i = 1; i <= 7; i++) {
            System.out.print("*");
        }
        System.out.println();
    }

    public static void lineOf35() {
        for (int i = 1; i <= 35; i++) {
            System.out.print("*");
        }
        System.out.println();
    }
    ...
```

- This code is redundant.
- Would variables help? Would constants help?
- What is a better solution?
  - `line` - A method to draw a line of any number of stars.
  - `box` - A method to draw a box of any size.

Parameterization

- **parameter**: A value passed to a method by its caller.
  - Instead of `lineOf7`, `lineOf13`, write `line` to draw any length.
    - When *declaring* the method, we will state that it requires a parameter for the number of stars.
    - When *calling* the method, we will specify how many stars to draw.



Declaring a parameter

Stating that a method requires a parameter in order to run

```
public static void name ( type name ) {
    statement(s);
}
```

- Example:

```
public static void sayPassword(int code) {
    System.out.println("The password is: " + code);
}
```

  - When `sayPassword` is called, the caller must specify the integer code to print.

Passing parameters

Calling a method and specifying values for its parameters

```
name (expression);
```

- Example:

```
public static void main(String[] args) {
    sayPassword(42);
    sayPassword(12345);
}
```

Output:

```
The password is 42
The password is 12345
```

Parameters and loops

- A parameter can guide the number of repetitions of a loop.

```
public static void main(String[] args) {
    chant(3);
}

public static void chant(int times) {
    for (int i = 1; i <= times; i++) {
        System.out.println("Just a salad...");
    }
}
```

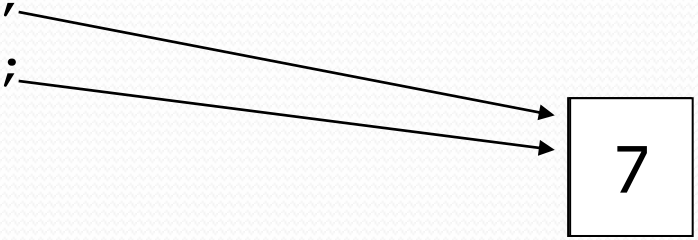
Output:

```
Just a salad...
Just a salad...
Just a salad...
```

How parameters are passed

- When the method is called:
  - The value is stored into the parameter variable.
  - The method's code executes using that value.

```
public static void main(String[] args) {
    chant(3);
    chant(7);
}

public static void chant(int times) {
    for (int i = 1; i <= times; i++) {
        System.out.println("Just a salad...");
    }
}
```



Common errors

- If a method accepts a parameter, it is illegal to call it without passing any value for that parameter.

```
chant();        // ERROR: parameter value required
```

- The value passed to a method must be of the correct type.

```
chant(3.7);     // ERROR: must be of type int
```

- Exercise: Change the `Stars` program to use a parameterized method for drawing lines of stars.

Stars solution

```
// Prints several lines of stars.
// Uses a parameterized method to remove redundancy.
public class Stars2 {
    public static void main(String[] args) {
        line(13);
        line(7);
        line(35);
    }

    // Prints the given number of stars plus a line break.
    public static void line(int count) {
        for (int i = 1; i <= count; i++) {
            System.out.print("*");
        }
        System.out.println();
    }
}
```

Multiple parameters

- A method can accept multiple parameters. (separate by ,)
  - When calling it, you must pass values for each parameter.

- Declaration:

```
public static void name (type name, ..., type name) {
    statement(s);
}
```

- Call:

```
methodName (value, value, ..., value);
```

Multiple parameters example

```
public static void main(String[] args) {
    printNumber(4, 9);
    printNumber(17, 6);
    printNumber(8, 0);
    printNumber(0, 8);
}

public static void printNumber(int number, int count) {
    for (int i = 1; i <= count; i++) {
        System.out.print(number);
    }
    System.out.println();
}
```

Output:

```
444444444
171717171717

00000000
```

- Modify the `Stars` program to draw boxes with parameters.

Stars solution

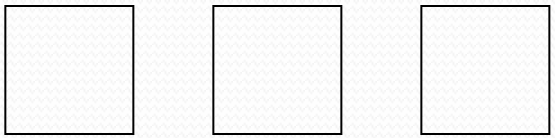
```
// Prints several lines and boxes made of stars.
// Third version with multiple parameterized methods.

public class Stars3 {
    public static void main(String[] args) {
        line(13);
        line(7);
        line(35);
        System.out.println();
        box(10, 3);
        box(5, 4);
        box(20, 7);
    }

    // Prints the given number of stars plus a line break.
    public static void line(int count) {
        for (int i = 1; i <= count; i++) {
            System.out.print("*");
        }
        System.out.println();
    }
    ...
```

Stars solution, cont'd.

```
...

    // Prints a box of stars of the given size.
    public static void box(int width, int height) {
        line(width);
        for (int line = 1; line <= height - 2; line++) {
            System.out.print("*");
            for (int space = 1; space <= width - 2; space++) {
                System.out.print(" ");
            }
            System.out.println("*");
        }
        line(width);
    }
}
```

A "Parameter Mystery" problem

```
public class ParameterMystery {
    public static void main(String[] args) {
        int x = 5;
        int y = 9;
        int z = 2;

        mystery(z, y, x);

        mystery(y, x, z);
    }

    public static void mystery(int x, int z, int y) {
        System.out.println(z + " " + y + " " + x);
    }
}
```



Strings

- **string**: A sequence of text characters.

```
String name = "text";
String name = expression;
```

  - Examples:

```
String name = "Marla Singer";

int x = 3;
int y = 5;
String point = "(" + x + ", " + y + ")";
```

Strings as parameters

```
public class StringParameters {
    public static void main(String[] args) {
        String teacher = "Helene";
        sayHello(teacher);
        sayHello("Marty");
    }

    public static void sayHello(String name) {
        System.out.println("Welcome, " + name);
    }
}
```

Output:

```
Welcome, Helene
Welcome, Marty
```

- Modify the `Stars` program to use string parameters. Use a method named `repeat` that prints a string many times.

Stars solution

```
// Prints several lines and boxes made of stars.
// Fourth version with String parameters.

public class Stars4 {
    public static void main(String[] args) {
        line(13);
        line(7);
        line(35);
        System.out.println();
        box(10, 3);
        box(5, 4);
        box(20, 7);
    }

    // Prints the given number of stars plus a line break.
    public static void line(int count) {
        repeat("*", count);
        System.out.println();
    }

    ...
```

Stars solution, cont'd.

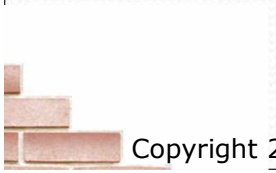
```
...

// Prints a box of stars of the given size.
public static void box(int width, int height) {
    line(width);

    for (int line = 1; line <= height - 2; line++) {
        System.out.print("*");
        repeat(" ", width - 2);
        System.out.println("*");
    }

    line(width);
}

// Prints the given String the given number of times.
public static void repeat(String s, int times) {
    for (int i = 1; i <= times; i++) {
        System.out.print(s);
    }
}

}
```

Building Java Programs

Graphics

reading: Supplement 3G

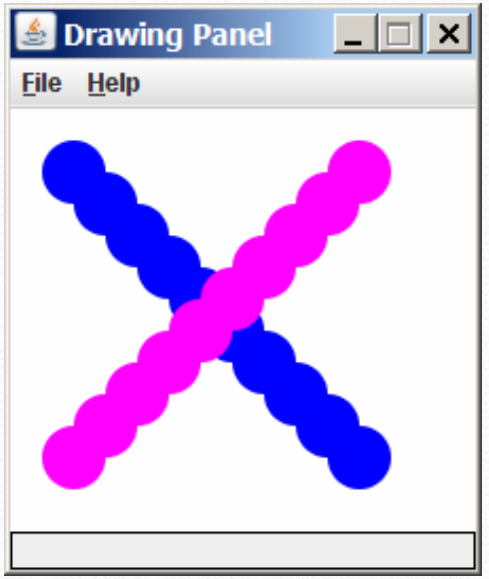
videos: Ch. 3G #1-2



Graphical objects

We will draw graphics in Java using 3 kinds of *objects*:

- `DrawingPanel`: A window on the screen.
  - Not part of Java; provided by the authors.
- `Graphics`: A "pen" to draw shapes/lines on a window.
- `Color`: Colors in which to draw shapes.



Objects (briefly)

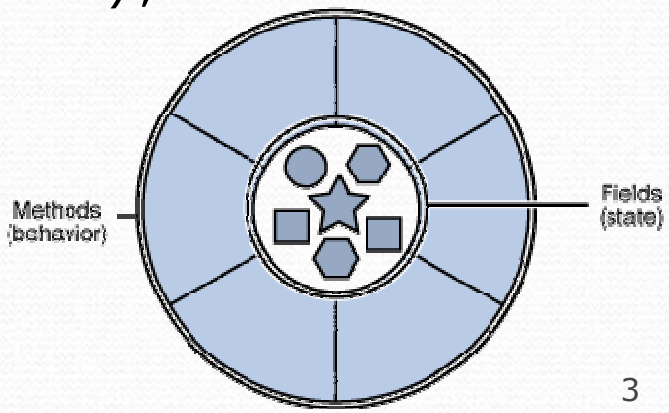
- **object:** An entity that contains data and behavior.
  - *data*: Variables inside the object.
  - *behavior*: Methods inside the object.
    - You interact with the methods; the data is hidden in the object.

- Constructing (creating) an object:

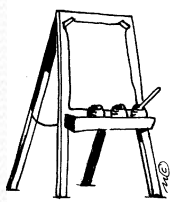
```
type objectName = new type(parameters);
```

- Calling an object's method:

```
objectName.methodName(parameters);
```



DrawingPanel



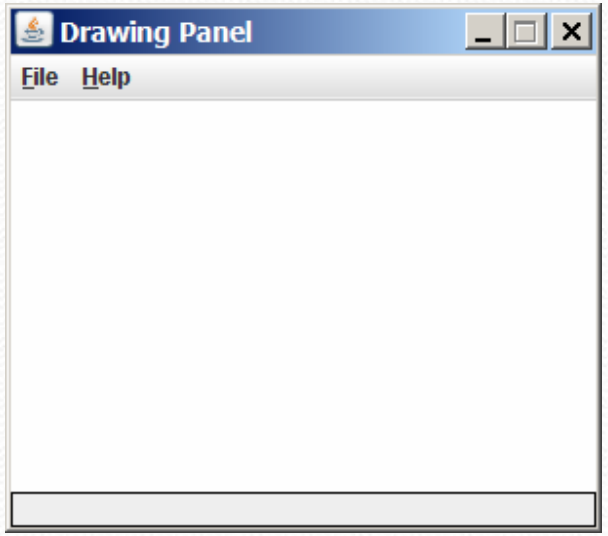
"Canvas" objects that represents windows/drawing surfaces

- To create a window:

```
DrawingPanel name = new DrawingPanel(width, height);
```

Example:

```
DrawingPanel panel = new DrawingPanel(300, 200);
```



- The window has nothing on it.
  - We can draw shapes and lines on it using another object of type `Graphics`.

Graphics

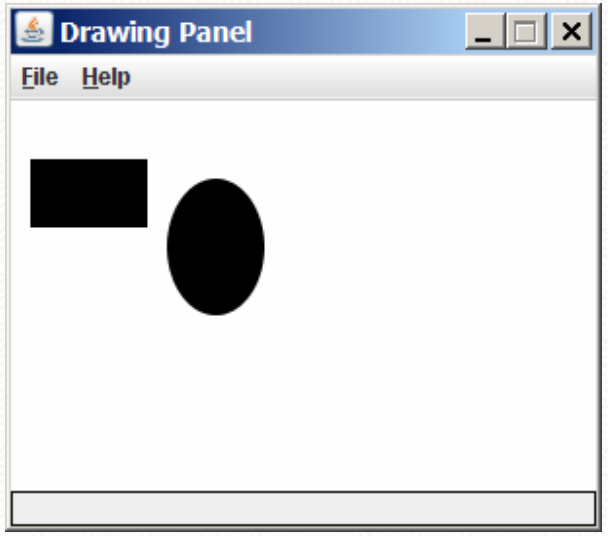
"Pen" objects that can draw lines and shapes

- Access it by calling `getGraphics` on your `DrawingPanel`.

```
Graphics g = panel.getGraphics();
```

- Draw shapes by calling methods on the `Graphics` object.

```
g.fillRect(10, 30, 60, 35);
g.fillOval(80, 40, 50, 70);
```



Java class libraries, import

- **Java class libraries**: Classes included with Java's JDK.
  - organized into groups named *packages*
  - To use a package, put an *import declaration* in your program.

- Syntax:

```
// put this at the very top of your program
import packageName.*;
```

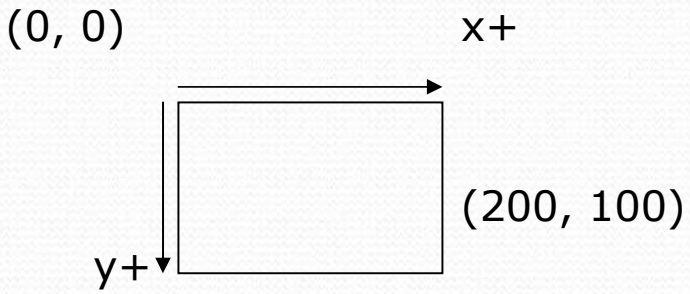
- `Graphics` is in a package named `java.awt`

```
import java.awt.*;
```

  - In order to use Graphics, you must place the above line at the very top of your program, before the `public class` header.

Coordinate system

- Each (x, y) position is a *pixel* ("picture element").
- (0, 0) is at the window's top-left corner.
  - x increases rightward and the y increases downward.
- The rectangle from (0, 0) to (200, 100) looks like this:



Graphics methods

Method name	Description
`g.drawLine(`**x1**, **y1**, **x2**, **y2**`);`	line between points (*x1*, *y1*), (*x2*, *y2*)
`g.drawOval(`**x**, **y**, **width**, **height**`);`	outline largest oval that fits in a box of size *width* * *height* with top-left at (*x*, *y*)
`g.drawRect(`**x**, **y**, **width**, **height**`);`	outline of rectangle of size *width* * *height* with top-left at (*x*, *y*)
`g.drawString(`**text**, **x**, **y**`);`	text with bottom-left at *(x, y)*
`g.fillOval(`**x**, **y**, **width**, **height**`);`	fill largest oval that fits in a box of size *width* * *height* with top-left at (*x*, *y*)
`g.fillRect(`**x**, **y**, **width**, **height**`);`	fill rectangle of size *width* * *height* with top-left at (*x*, *y*)
`g.setColor(`**Color**`);`	set `Graphics` to paint any following shapes in the given color

Color

- Create one using Red-Green-Blue (RGB) values from 0-255

```
Color name = new Color(red, green, blue);
```

  - Example:

```
Color brown = new Color(192, 128, 64);
```

- Or use a predefined `Color` class constant (more common)

```
Color.CONSTANT_NAME
```

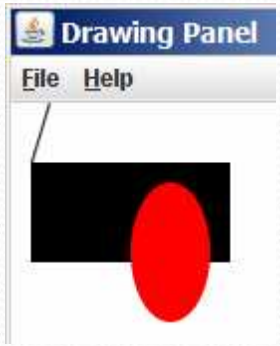
  where **CONSTANT_NAME** is one of:

  - `BLACK, BLUE, CYAN, DARK_GRAY, GRAY, GREEN, LIGHT_GRAY, MAGENTA, ORANGE, PINK, RED, WHITE, or YELLOW`

Using Colors

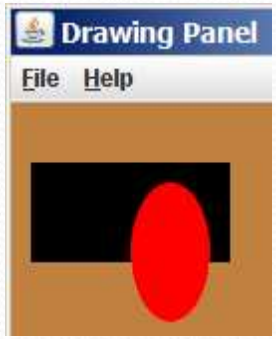
- Pass a `Color` to `Graphics` object's `setColor` method
  - Subsequent shapes will be drawn in the new color.

```
g.setColor(Color.BLACK);
g.fillRect(10, 30, 100, 50);
g.drawLine(20, 0, 10, 30);
g.setColor(Color.RED);
g.fillOval(60, 40, 40, 70);
```



- Pass a color to `DrawingPanel`'s `setBackground` method
  - The overall window background color will change.

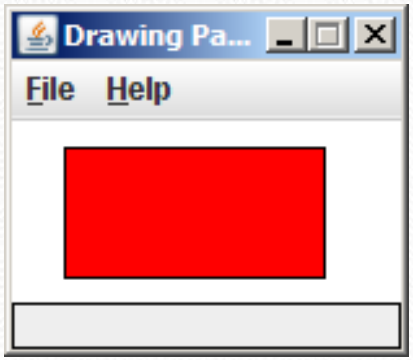
```
Color brown = new Color(192, 128, 64);
panel.setBackground(brown);
```



Outlined shapes

- To draw a colored shape with an outline, first *fill* it, then *draw* the same shape in the outline color.

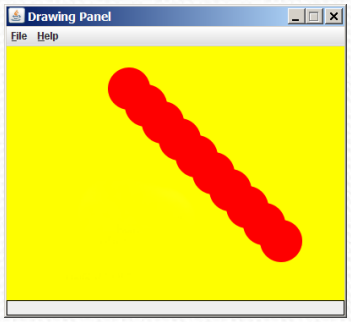
```
import java.awt.*;  // so I can use Graphics
public class OutlineExample {
    public static void main(String[] args) {
        DrawingPanel panel = new DrawingPanel(150, 70);
        Graphics g = panel.getGraphics();
        // inner red fill
        g.setColor(Color.RED);
        g.fillRect(20, 10, 100, 50);
        // black outline
        g.setColor(Color.BLACK);
        g.drawRect(20, 10, 100, 50);
    }
}
```



Drawing with loops

- The *x*,*y*, *w*,*h* expression can use the loop counter variable:

```
DrawingPanel panel = new DrawingPanel(400, 300);
panel.setBackground(Color.YELLOW);
Graphics g = panel.getGraphics();

g.setColor(Color.RED);
for (int i = 1; i <= 10; i++) {
    g.fillOval(100 + 20 * i, 5 + 20 * i, 50, 50);
}
```



- Nested loops are okay as well:

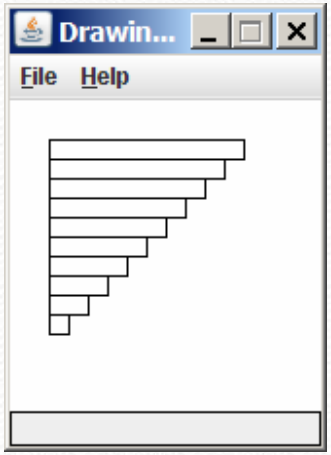
```
DrawingPanel panel = new DrawingPanel(250, 250);
Graphics g = panel.getGraphics();
g.setColor(Color.BLUE);

for (int x = 1; x <= 4; x++) {
    for (int y = 1; y <= 9; y++) {
        g.drawString("Java", x * 40, y * 25);
    }
}
```

Loops that begin at 0

- Beginning at 0 and using < can make coordinates easier.

- Example:
  - Draw ten stacked rectangles starting at (20, 20), height 10, width starting at 100 and decreasing by 10 each time:

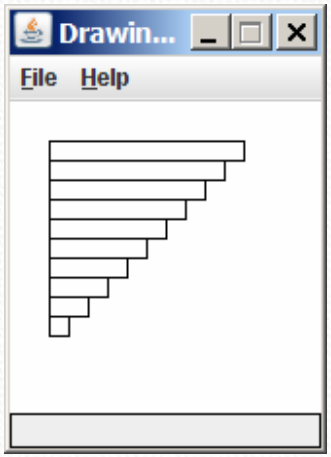
```
DrawingPanel panel = new DrawingPanel(160, 160);
Graphics g = panel.getGraphics();

for (int i = 0; i < 10; i++) {
    g.drawRect(20, 20 + 10 * i, 100 - 10 * i, 10);
}
```



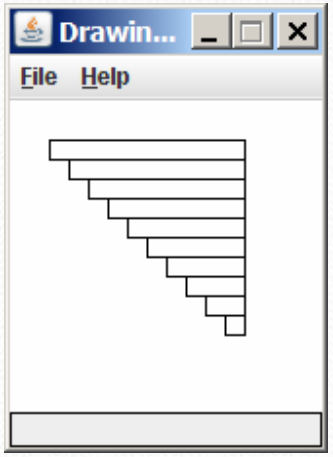
Drawing w/ loops questions

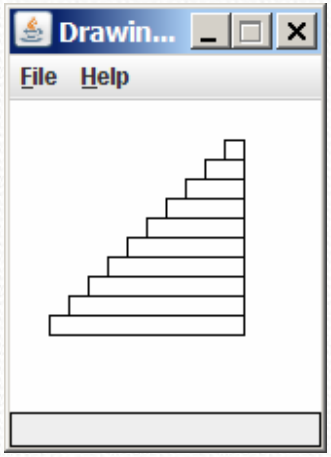
- Code from previous slide:

```
DrawingPanel panel = new DrawingPanel(160, 160);
Graphics g = panel.getGraphics();

for (int i = 0; i < 10; i++) {
    g.drawRect(20, 20 + 10 * i, 100 - 10 * i, 10);
}
```



- Write variations of the above program that draw the figures at right as output.

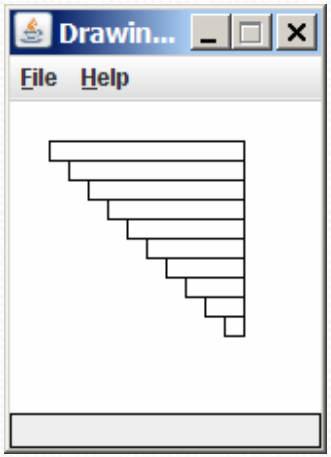




Drawing w/ loops answers

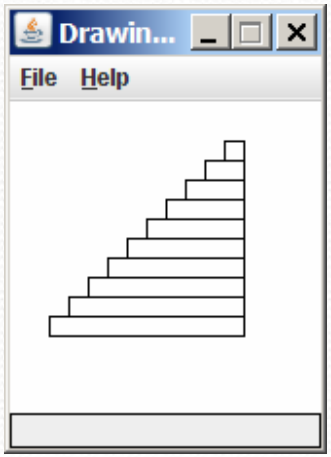
- Solution #1:

```
Graphics g = panel.getGraphics();
for (int i = 0; i < 10; i++) {
    g.drawRect(20 + 10 * i, 20 + 10 * i,
               100 - 10 * i, 10);
}
```



- Solution #2:

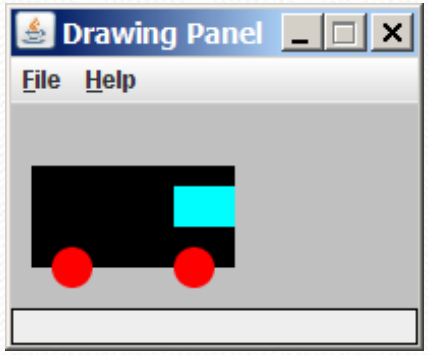
```
Graphics g = panel.getGraphics();
for (int i = 0; i < 10; i++) {
    g.drawRect(110 - 10 * i, 20 + 10 * i,
               10 + 10 * i, 10);
}
```



Superimposing shapes

- When ≥ 2 shapes occupy the same pixels, the last drawn "wins."

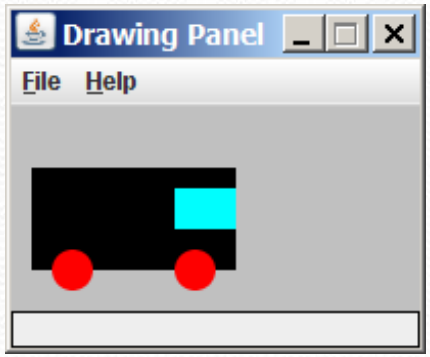
```
import java.awt.*;

public class Car {
    public static void main(String[] args) {
        DrawingPanel panel = new DrawingPanel(200, 100);
        panel.setBackground(Color.LIGHT_GRAY);
        Graphics g = panel.getGraphics();

        g.setColor(Color.BLACK);
        g.fillRect(10, 30, 100, 50);

        g.setColor(Color.RED);
        g.fillOval(20, 70, 20, 20);
        g.fillOval(80, 70, 20, 20);

        g.setColor(Color.CYAN);
        g.fillRect(80, 40, 30, 20);
    }
}
```



Drawing with methods

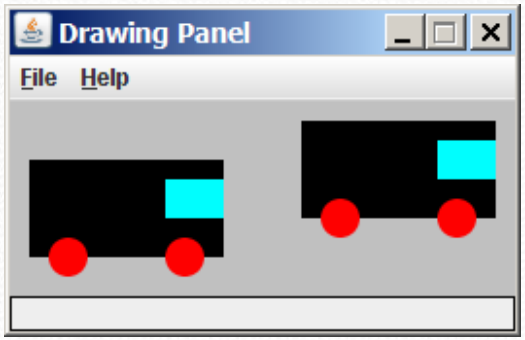
- To draw in multiple methods, you must pass `Graphics g`.

```
import java.awt.*;

public class Car2 {
    public static void main(String[] args) {
        DrawingPanel panel = new DrawingPanel(200, 100);
        panel.setBackground(Color.LIGHT_GRAY);
        Graphics g = panel.getGraphics();
        drawCar(g);
    }

    public static void drawCar(Graphics g) {
        g.setColor(Color.BLACK);
        g.fillRect(10, 30, 100, 50);

        g.setColor(Color.RED);
        g.fillOval(20, 70, 20, 20);
        g.fillOval(80, 70, 20, 20);

        g.setColor(Color.CYAN);
        g.fillRect(80, 40, 30, 20);
    }
}
```



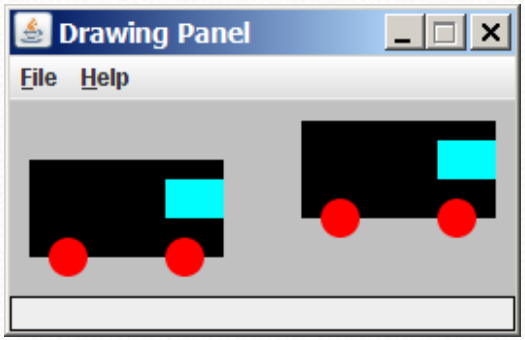
Parameterized figures

- Modify the car-drawing method so that it can draw cars at different positions, as in the following image.
  - Top-left corners: (10, 30), (150, 10)



Parameterized answer

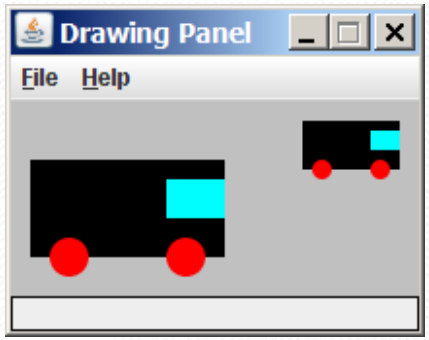
```
import java.awt.*;

public class Car3 {
    public static void main(String[] args) {
        DrawingPanel panel = new DrawingPanel(260, 100);
        panel.setBackground(Color.LIGHT_GRAY);
        Graphics g = panel.getGraphics();
        drawCar(g, 10, 30);
        drawCar(g, 150, 10);
    }

    public static void drawCar(Graphics g, int x, int y) {
        g.setColor(Color.BLACK);
        g.fillRect(x, y, 100, 50);

        g.setColor(Color.RED);
        g.fillOval(x + 10, y + 40, 20, 20);
        g.fillOval(x + 70, y + 40, 20, 20);

        g.setColor(Color.CYAN);
        g.fillRect(x + 70, y + 10, 30, 20);
    }
}
```

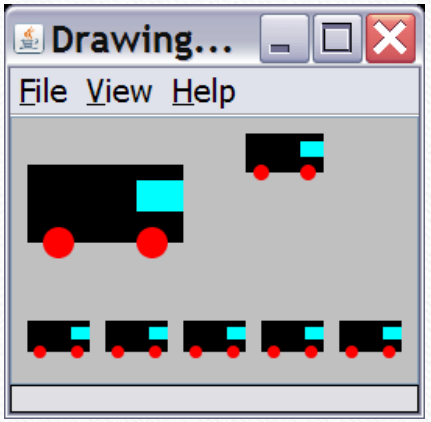


Drawing parameter question

- Modify `drawCar` to allow the car to be drawn at any size.
  - Existing car: size 100
  - Second car: size 50, top/left at (150, 10)

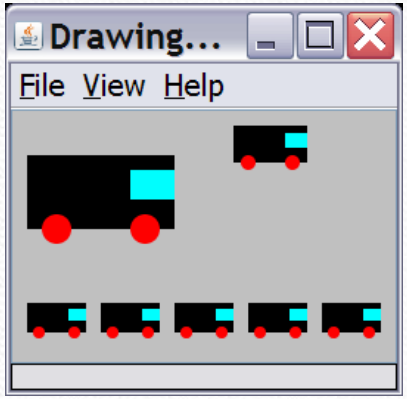
- Then use a `for` loop to draw a line of cars.
  - Start at (10, 130), each car size 40, separated by 50px.





Drawing parameter answer

```
import java.awt.*;

public class Car4 {
    public static void main(String[] args) {
        DrawingPanel panel = new DrawingPanel(210, 100);
        panel.setBackground(Color.LIGHT_GRAY);

        Graphics g = panel.getGraphics();
        drawCar(g, 10, 30, 100);
        drawCar(g, 150, 10, 50);

        for (int i = 0; i < 5; i++) {
            drawCar(g, 10 + i * 50, 130, 40);
        }
    }

    public static void drawCar(Graphics g, int x, int y, int size) {
        g.setColor(Color.BLACK);
        g.fillRect(x, y, size, size / 2);

        g.setColor(Color.RED);
        g.fillOval(x + size / 10, y + 2 * size / 5,
                   size / 5, size / 5);
        g.fillOval(x + 7 * size / 10, y + 2 * size / 5,
                   size / 5, size / 5);

        g.setColor(Color.CYAN);
        g.fillRect(x + 7 * size / 10, y + size / 10,
                   3 * size / 10, size / 5);
    }
}
```

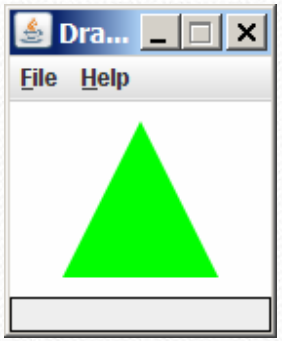


Polygon

Objects that represent arbitrary shapes

- Add points to a `Polygon` using its `addPoint(x, y)` method.
- Example:

```
DrawingPanel p = new DrawingPanel(100, 100);
Graphics g = p.getGraphics();
g.setColor(Color.GREEN);

Polygon poly = new Polygon();
poly.addPoint(10, 90);
poly.addPoint(50, 10);
poly.addPoint(90, 90);
g.fillPolygon(poly);
```



Animation with sleep

- DrawingPanel's sleep method pauses your program for a given number of milliseconds.

- You can use sleep to create simple animations.

```
DrawingPanel panel = new DrawingPanel(250, 200);
Graphics g = panel.getGraphics();

g.setColor(Color.BLUE);
for (int i = 1; i <= 10; i++) {
    g.fillOval(15 * i, 15 * i, 30, 30);
    panel.sleep(500);
}
```

  - Try adding sleep commands to loops in past exercises in this chapter and watch the panel draw itself piece by piece.

Building Java Programs

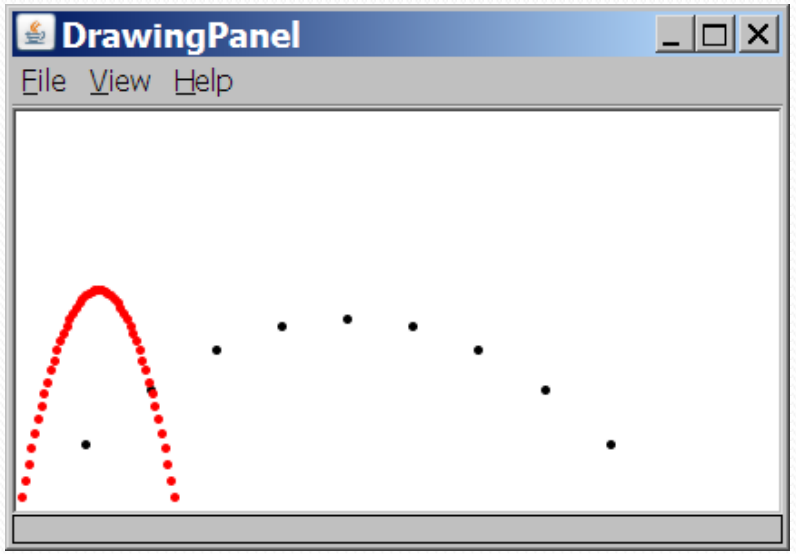
Chapter 3
Lecture 3-2: Return; `double`; `System.out.printf`

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

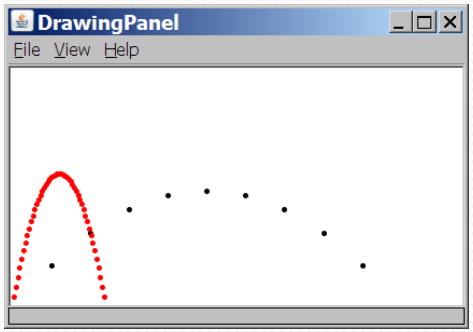
```
step         x         y     time
   0      0.00      0.00     0.00
   1     36.14     38.76     0.94
   2     72.28     68.91     1.87
   3    108.42     90.45     2.81
   4    144.56    103.37     3.75
   5    180.70    107.67     4.69
   6    216.84    103.37     5.62
   7    252.98     90.45     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
  ...
```



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.

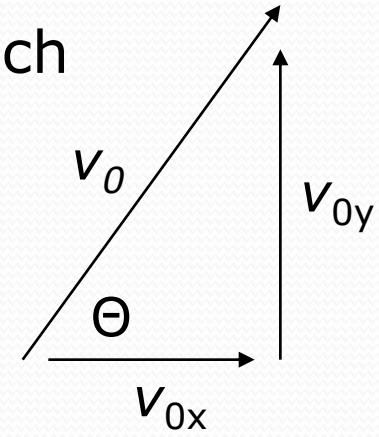
```
step         x         y     time
   0      0.00      0.00     0.00
   1     36.14     38.76     0.94
   2     72.28     68.91     1.87
  ...
  10    361.40      0.00     9.37
```



- Total time is based on the force of gravity on the projectile.
  - Force of gravity (g) $\cong$ 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.
  - $v_t = -v_0$
    $-v_0 = v_0 + a\,t$
    $\boldsymbol{t = -2\,v_0 / a}$

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
`E`	2.7182818...
`PI`	3.1415926...

Calling `Math` methods

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

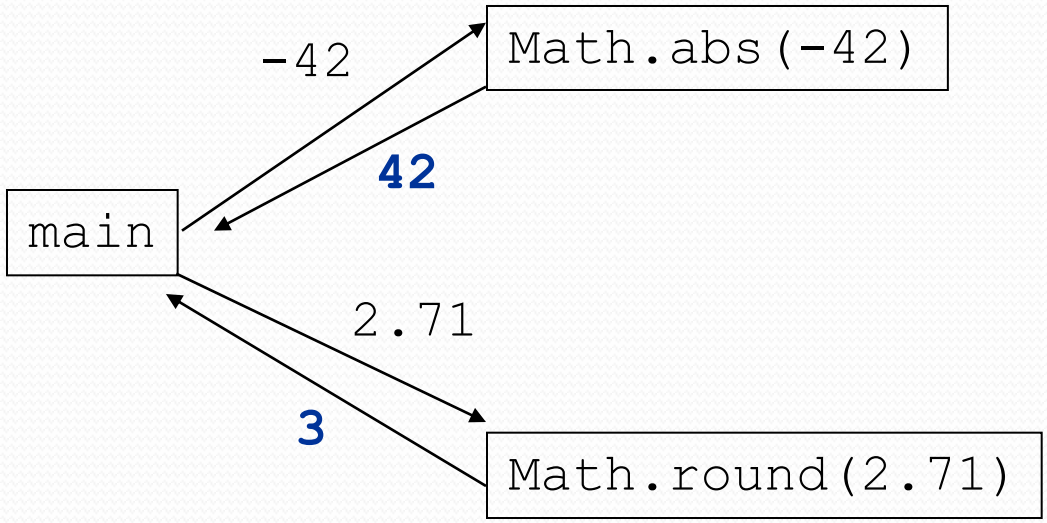
- Examples:

```
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` 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.round(Math.PI) + Math.round(Math.E)`
  - `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?

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 exact division from `/`
  - 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);
```

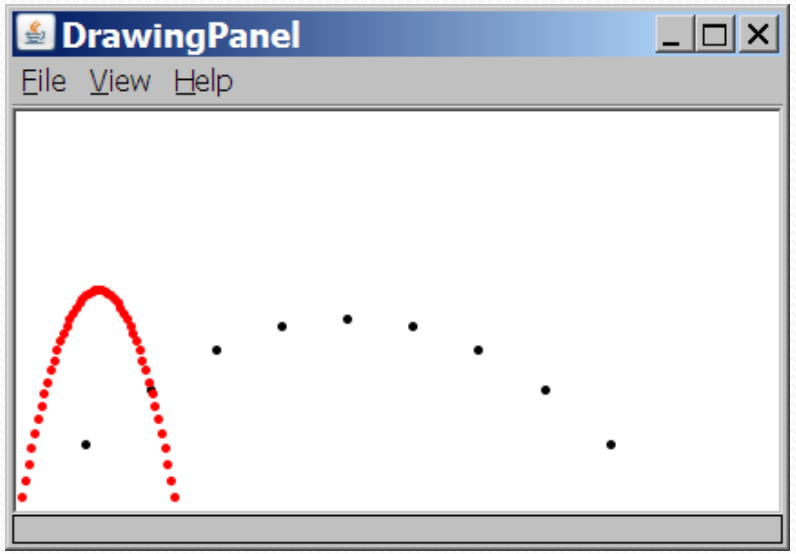
  - Output:

```
45       1.23
   1.234 1.2 1.23457
```

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
  ...
```



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);
        }
    }
}
```

Building Java Programs

Chapter 3
Lecture 3-3: Interactive Programs w/ Scanner

reading: 3.3 - 3.4
self-check: #16-19
exercises: #11
videos: Ch. 3 #4

Interactive programs

- We have written programs that print console output, but it is also possible to read *input* from the console.
  - The user types input into the console. We capture the input and use it in our program.
  - Such a program is called an *interactive program*.

- Interactive programs can be challenging.
  - Computers and users think in very different ways.
  - Users misbehave.

Input and `System.in`

- `System.out`
  - An object with methods named `println` and `print`
- `System.in`
  - not intended to be used directly
  - We use a second object, from a class `Scanner`, to help us.

- Constructing a `Scanner` object to read console input:

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

  - Example:

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

Java class libraries, import

- **Java class libraries**: Classes included with Java's JDK.
  - organized into groups named *packages*
  - To use a package, put an *import declaration* in your program.

- Syntax:

```
// put this at the very top of your program
import packageName.*;
```

- `Scanner` is in a package named `java.util`

```
import java.util.*;
```

  - To use `Scanner`, you must place the above line at the top of your program (before the `public class` header).

`Scanner` methods

Method	Description
`nextInt()`	reads a token of user input as an `int`
`nextDouble()`	reads a token of user input as a `double`
`next()`	reads a token of user input as a `String`
`nextLine()`	reads a *line* of user input as a `String`

- Each method waits until the user presses Enter.
  - The value typed is returned.

```
System.out.print("How old are you? ");     // prompt
int age = console.nextInt();
System.out.println("You'll be 40 in " +
        (40 - age) + " years.");
```

  - **prompt**: A message telling the user what input to type.

Example `Scanner` usage

```
import java.util.*;   // so that I can use Scanner

public class ReadSomeInput {
    public static void main(String[] args) {
        Scanner console = new Scanner(System.in);

        System.out.print("How old are you? ");
        int age = console.nextInt();

        System.out.println(age + "... That's quite old!");
    }
}
```

- Output (user input underlined):

```
How old are you? 14
14... That's quite old!
```

Another `Scanner` example

```
import java.util.*;   // so that I can use Scanner

public class ScannerSum {
    public static void main(String[] args) {
        Scanner console = new Scanner(System.in);

        System.out.print("Please type three numbers: ");
        int num1 = console.nextInt();
        int num2 = console.nextInt();
        int num3 = console.nextInt();

        int sum = num1 + num2 + num3;
        System.out.println("The sum is " + sum);
    }
}
```

- Output (user input underlined):

```
Please type three numbers: 8 6 13
The sum is 27
```

  - The `Scanner` can read multiple values from one line.

Input tokens

- **token**: A unit of user input, as read by the `Scanner`.
  - Tokens are separated by *whitespace* (spaces, tabs, newlines).
  - How many tokens appear on the following line of input?

```
23  John Smith   42.0 "Hello world"   $2.50   " 19"
```

- When a token is not the type you ask for, it crashes.

```
System.out.print("What is your age? ");
int age = console.nextInt();
```

Output:

```
What is your age? Timmy
java.util.InputMismatchException
        at java.util.Scanner.next(Unknown Source)
        at java.util.Scanner.nextInt(Unknown Source)
        ...
```

Scanners as parameters

- If many methods read input, declare a `Scanner` in `main` and pass it to the others as a parameter.

```
public static void main(String[] args) {
    Scanner console = new Scanner(System.in);
    int sum = readSum3(console);
    System.out.println("The sum is " + sum);
}

// Prompts for 3 numbers and returns their sum.
public static int readSum3(Scanner console) {
    System.out.print("Type 3 numbers: ");
    int num1 = console.nextInt();
    int num2 = console.nextInt();
    int num3 = console.nextInt();
    return num1 + num2 + num3;
}
```

Cumulative sum

reading: 4.1

self-check: Ch. 4 #1-3

exercises: Ch. 4 #1-6

Adding many numbers

- How would you find the sum of all integers from 1-1000?

```
int sum = 1 + 2 + 3 + 4 + ... ;
System.out.println("The sum is " + sum);
```

- What if we want the sum from 1 - 1,000,000?
  Or the sum up to any maximum?

- We could write a method that accepts the max value as a parameter and prints the sum.
  - How can we generalize code like the above?

A failed attempt

- An incorrect solution for summing 1-1000:

```
for (int i = 1; i <= 1000; i++) {
    int sum = 0;
    sum = sum + i;
}

// sum is undefined here
System.out.println("The sum is " + sum);
```

  - `sum`'s scope is in the `for` loop, so the code does not compile.

- **cumulative sum**: A variable that keeps a sum in progress and is updated repeatedly until summing is finished.
  - The `sum` in the above code is an attempt at a cumulative sum.

Fixed cumulative sum loop

- A corrected version of the sum loop code:

```
int sum = 0;
for (int i = 1; i <= 1000; i++) {
    sum = sum + i;
}
System.out.println("The sum is " + sum);
```

Key idea:

- Cumulative sum variables must be declared *outside* the loops that update them, so that they will exist after the loop.

Cumulative product

- This cumulative idea can be used with other operators:

```
int product = 1;
for (int i = 1; i <= 20; i++) {
    product = product * 2;
}
System.out.println("2 ^ 20 = " + product);
```

  - How would we make the base and exponent adjustable?

Scanner and cumulative sum

- We can do a cumulative sum of user input:

```
Scanner console = new Scanner(System.in);
int sum = 0;
for (int i = 1; i <= 100; i++) {
    System.out.print("Type a number: ");
    sum = sum + console.nextInt();
}
System.out.println("The sum is " + sum);
```

User-guided cumulative sum

```
Scanner console = new Scanner(System.in);
System.out.print("How many numbers to add? ");
int count = console.nextInt();

int sum = 0;
for (int i = 1; i <= count; i++) {
    System.out.print("Type a number: ");
    sum = sum + console.nextInt();
}
System.out.println("The sum is " + sum);
```

- Output:

```
How many numbers to add? 3
Type a number: 2
Type a number: 6
Type a number: 3
The sum is 11
```

Cumulative sum question

- Write a program that reads two employees' hours and displays each employee's total and the overall total hours.
  - The company doesn't pay overtime; cap each day at 8 hours.
- Example log of execution:

```
Employee 1: How many days? 3
Hours? 6
Hours? 12
Hours? 5
Employee 1's total hours = 19 (6.3 / day)

Employee 2: How many days? 2
Hours? 11
Hours? 6
Employee 2's total hours = 14 (7.0 / day)

Total hours for both = 33
```

Cumulative sum answer

```
// Computes the total paid hours worked by two employees.
// The company does not pay for more than 8 hours per day.
// Uses a "cumulative sum" loop to compute the total hours.

import java.util.*;

public class Hours {
    public static void main(String[] args) {
        Scanner console = new Scanner(System.in);

        int hours1 = processEmployee(console, 1);
        int hours2 = processEmployee(console, 2);

        int total = hours1 + hours2;
        System.out.println("Total hours for both = " + total);
    }

    ...
```

Cumulative sum answer 2

```
    ...

    // Reads hours information about an employee with the given number.
    // Returns total hours worked by the employee.
    public static int processEmployee(Scanner console, int number) {
        System.out.print("Employee " + number + ": How many days? ");
        int days = console.nextInt();

        // totalHours is a cumulative sum of all days' hours worked.
        int totalHours = 0;
        for (int i = 1; i <= days; i++) {
            System.out.print("Hours? ");
            int hours = console.nextInt();
            totalHours = totalHours + Math.min(hours, 8);
        }

        double hoursPerDay = (double) totalHours / days;
        System.out.printf("Employee %d's total hours = %d (%.1f / day)\n",
                          number, totalHours, hoursPerDay);
        System.out.println();
        return totalHours;
    }
}
```

Cumulative sum question

- Write a modified version of the `Receipt` program from Ch.2 that prompts the user for how many people ate and how much each person's dinner cost.
  - Display results in format below, with `$` and 2 digits after the `.`
- Example log of execution:

```
How many people ate? 4
Person #1: How much did your dinner cost? 20.00
Person #2: How much did your dinner cost? 15
Person #3: How much did your dinner cost? 25.0
Person #4: How much did your dinner cost? 10.00

Subtotal: $70.00
Tax: $5.60
Tip: $10.50
Total: $86.10
```

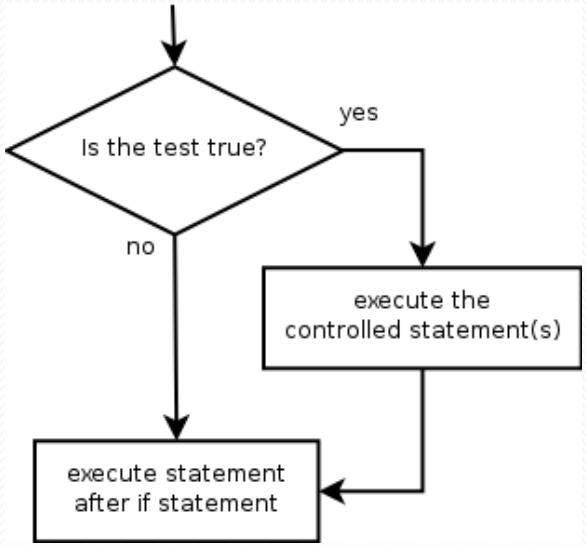
Cumulative sum answer

```
// This program enhances our Receipt program using a cumulative sum.
import java.util.*;

public class Receipt2 {
    public static void main(String[] args) {
        Scanner console = new Scanner(System.in);
        System.out.print("How many people ate? ");
        int people = console.nextInt();
        double subtotal = 0.0;              // cumulative sum

        for (int i = 1; i <= people; i++) {
            System.out.print("Person #" + i +
                             ": How much did your dinner cost? ");
            double personCost = console.nextDouble();
            subtotal = subtotal + personCost;  // add to sum
        }
        results(subtotal);
    }

    // Calculates total owed, assuming 8% tax and 15% tip
    public static void results(double subtotal) {
        double tax = subtotal * .08;
        double tip = subtotal * .15;
        double total = subtotal + tax + tip;

        System.out.printf("Subtotal: $%.2f\n", subtotal);
        System.out.printf("Tax: $%.2f\n", tax);
        System.out.printf("Tip: $%.2f\n", tip);
        System.out.printf("Total: $%.2f\n", total);
    }
}
```

The `if` statement

Executes a block of statements only if a test is true

```
if (test) {
    statement;
    ...
    statement;
}
```



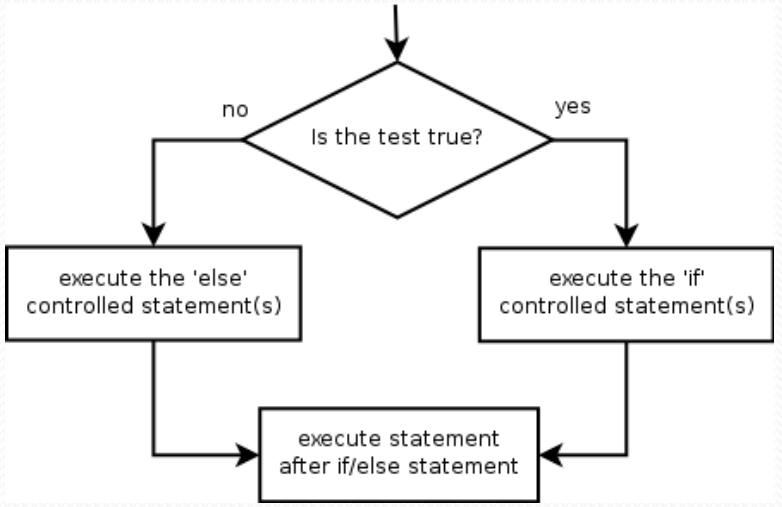
- Example:

```
double gpa = console.nextDouble();
if (gpa >= 2.0) {
    System.out.println("Application accepted.");
}
```

The `if/else` statement

Executes one block if a test is true, another if false

```
if (test) {
    statement(s);
} else {
    statement(s);
}
```



- Example:

```
double gpa = console.nextDouble();
if (gpa >= 2.0) {
    System.out.println("Welcome to Mars University!");
} else {
    System.out.println("Application denied.");
}
```

Relational expressions

- A **test** in an `if` is the same as in a `for` loop.

```
for (int i = 1; i <= 10; i++) { ...
if (i <= 10) { ...
```

  - These are `boolean` expressions, seen in Ch. 5.

- Tests use *relational operators*:

Operator	Meaning	Example	Value
==	equals	1 + 1 == 2	true
!=	does not equal	3.2 != 2.5	true
<	less than	10 < 5	false
>	greater than	10 > 5	true
<=	less than or equal to	126 <= 100	false
>=	greater than or equal to	5.0 >= 5.0	true

Logical operators: &&, ||, !

- Conditions can be combined using *logical operators*:

Operator	Description	Example	Result
`&&`	and	`(2 == 3) && (-1 < 5)`	`false`
`||`	or	`(2 == 3) || (-1 < 5)`	`true`
`!`	not	`!(2 == 3)`	`true`

- "Truth tables" for each, used with logical values *p* and *q*:

p	q	p && q	p || q
true	true	true	true
true	false	false	true
false	true	false	true
false	false	false	false

p	!p
true	false
false	true

Evaluating logic expressions

- Relational operators have lower precedence than math.

```
5 * 7 >= 3 + 5 * (7 - 1)
5 * 7 >= 3 + 5 * 6
35    >= 3 + 30
35    >= 33
true
```

- Relational operators cannot be "chained" as in algebra.

```
2 <= x <= 10          (assume that x is 15)
true   <= 10
   error!
```

  - Instead, combine multiple tests with `&&` or `||`

```
2 <= x && x <= 10     (assume that x is 15)
true   && false
   false
```

Logical questions

- What is the result of each of the following expressions?

```
int x = 42;
int y = 17;
int z = 25;
```

  - `y < x && y <= z`
  - `x % 2 == y % 2 || x % 2 == z % 2`
  - `x <= y + z && x >= y + z`
  - `!(x < y && x < z)`
  - `(x + y) % 2 == 0 || !((z - y) % 2 == 0)`

- Answers: `true`, `false`, `true`, `true`, `false`