# Bethune Class Representative

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- tutorials in Bethune College Room 203
  - Thu 2:30PM to 4:00PM
  - Fri 4:00PM to 5:30PM

- Bethune College Committee and Peer Leaders Meet and Greet in Bethune College 320
  - Sep 26 4:00PM to 5:30PM
- bethune.yorku.ca/classreps/attendees

# Classes (Part 2)

Implementing non-static features

# Goals

- finish implementing the immutable class **`PhoneNumber`**
  - **`equals()`**
- implement a mutable class

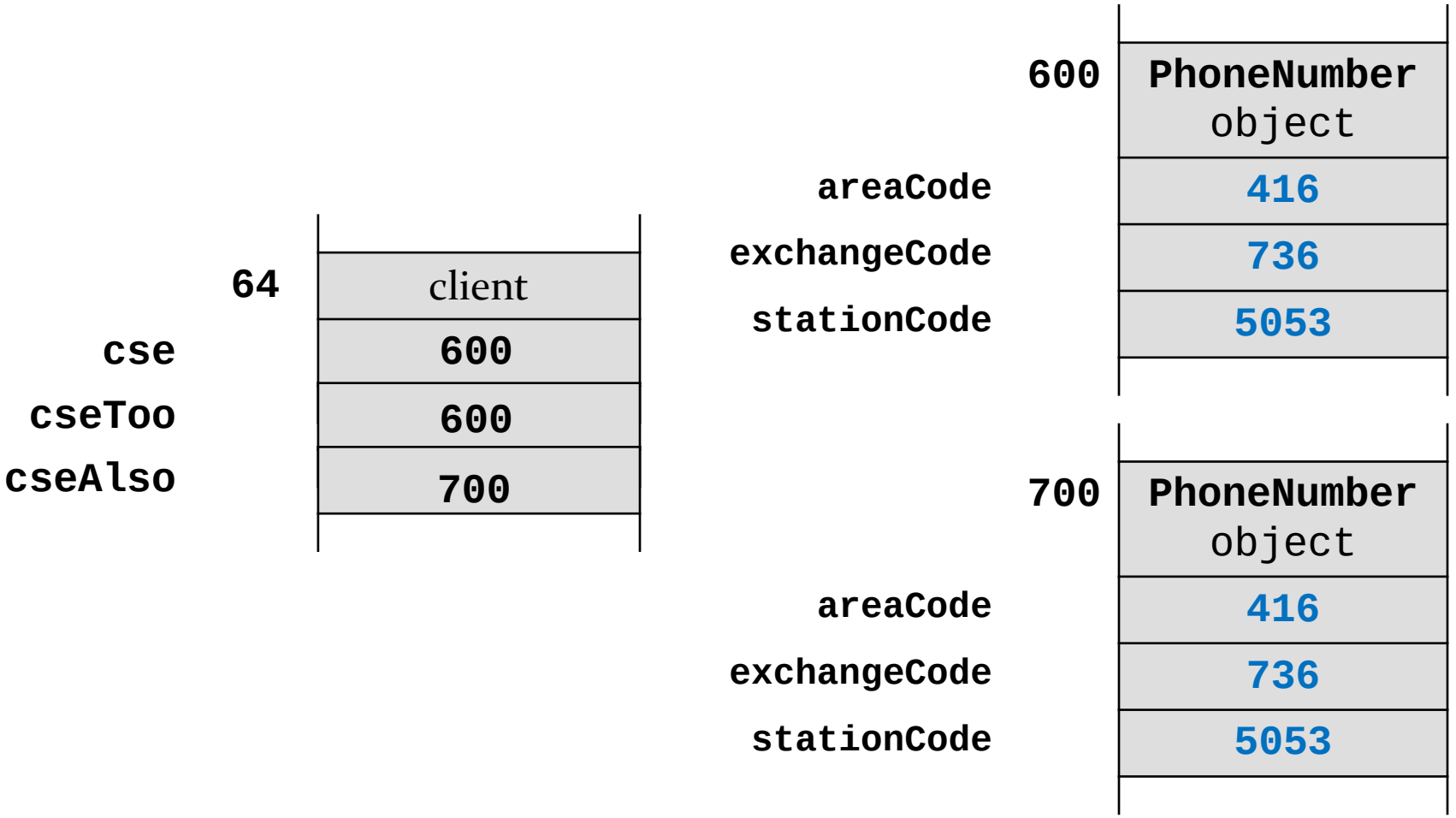
# Overriding `equals()`

- suppose you write a value class that extends **`Object`** but you do not override **`equals()`**
  - what happens when a client tries to use **`equals()`**?
    - **`Object.equals()`** is called

```
// PhoneNumber client

PhoneNumber cse = new PhoneNumber(416, 736, 5053);
System.out.println( cse.equals(cse) );        // true

PhoneNumber cseToo = cse;
System.out.println( cseToo.equals(cse) );     // true

PhoneNumber cseAlso = new PhoneNumber(416, 736, 5053);
System.out.println( cseAlso.equals(cse) );    // false!
```



[notes 2.2.4]


64
client
cse
600
cseTo
600
cseAlso
700
600
PhoneNumber
object
areaCode
416
exchangeCode
736
stationCode
5053
700
PhoneNumber
object
areaCode
416
exchangeCode
736
stationCode
5053

# `Object.equals()`

- **`Object.equals()`** checks if two references refer to the same object
  - **`x.equals(y)`** is true if and only if **`x`** and **`y`** are references to the same object

# `PhoneNumber.equals()`

- most value classes should support logical equality
  - an instance is equal to another instance if their states are equal
    - e.g. two **`PhoneNumbers`** are equal if their area, exchange, and station codes have the same values

- implementing **`equals()`** is surprisingly hard
  - "One would expect that overriding **`equals()`**, since it is a fairly common task, should be a piece of cake. The reality is far from that. There is an amazing amount of disagreement in the Java community regarding correct implementation of **`equals()`**. Look into the best Java source code or open an arbitrary Java textbook and take a look at what you find. Chances are good that you will find several different approaches and a variety of recommendations."
    - Angelika Langer, Secrets of equals() – Part 1
  - `http://www.angelikalanger.com/Articles/JavaSolutions/SecretsOfEquals/Equals.html`

- what we are about to do does not always produce the result you might be looking for
  - but it is always satisfies the **`equals()`** contract
  - and it's what the notes and textbook do

# CSE1030 Requirements for `equals`

1. an instance is equal to itself
2. an instance is never equal to `null`
3. only instances of the exact same type can be equal
4. instances with the same state are equal

# 1. An Instance is Equal to Itself

- **`x.equals(x)`** should always be **`true`**
- also, **`x.equals(y)`** should always be true if **`x`** and **`y`** are references to the same object
- you can check if two references are equal using **`==`**

```
@Override
public boolean equals(Object obj) {
  if (this == obj) {
    return true;
  }

}
```

# 2. An Instance is Never Equal to `null`

- Java requires that **`x.equals(null)`** returns **`false`**
- and you must not throw an exception if the argument is **`null`**
  - so it looks like we have to check for a **`null`** argument…

```
@Override
public boolean equals(Object obj) {
  if (this == obj) {
    return true;
  }
  if (obj == null) {
    return false;
  }


}
```

# 3. Instances of the Same Type can be Equal

- the implementation of **`equals()`** used in the notes and the textbook is based on the rule that an instance can only be equal to another instance of the same type
- you can find the class of an object using **`Object.getClass()`**

```
public final Class<? extends Object> getClass()
```

- Returns the runtime class of an object.

```
@Override
public boolean equals(Object obj) {
  if (this == obj) {
    return true;
  }
  if (obj == null) {
    return false;
  }
  if (this.getClass() != obj.getClass()) {
    return false;
  }


}
```

# Instances with Same State are Equal

- recall that the value of the attributes of an object define the state of the object
  - two instances are equal if all of their attributes are equal

- unfortunately, we cannot yet retrieve the attributes of the parameter **`obj`** because it is declared to be an **`Object`** in the method signature
  - we need a cast

```
@Override
public boolean equals(Object obj) {
  if (this == obj) {
    return true;
  }
  if (obj == null) {
    return false;
  }
  if (this.getClass() != obj.getClass()) {
    return false;
  }
  PhoneNumber other = (PhoneNumber) obj;


}
```

# Instances with Same State are Equal

- there is a recipe for checking equality of fields

1. if the field is a primitive type other than **`float`** or **`double`** use **`==`**
2. if the attribute type is **`float`** use **`Float.compare()`**
3. if the attribute type is **`double`** use **`Double.compare()`**
4. if the attribute is an array consider **`Arrays.equals()`**
5. if the attribute is a reference type use **`equals()`**, but beware of attributes that might be null

```java
@Override
public boolean equals(Object obj) {
  if (this == obj) {
    return true;
  }
  if (obj == null) {
    return false;
  }
  if (this.getClass() != obj.getClass()) {
    return false;
  }
  PhoneNumber other = (PhoneNumber) obj;
  if (areaCode != other.areaCode) {
    return false;
  }
  if (exchangeCode != other.exchangeCode) {
    return false;
  }
  if (stationCode != other.stationCode) {
    return false;
  }
  return true;
}
```

# The `equals()` Contract

- for reference values `equals()` is
  1. reflexive
  2. symmetric
  3. transitive
  4. consistent
  5. must not throw an exception when passed `null`

# The `equals()` contract: Reflexivity

1. reflexive :
   - an object is equal to itself
   - `x.equals(x)` is `true`

# The `equals()` contract: Symmetry

2. symmetric :
   - two objects must agree on whether they are equal
   - `x.equals(y)` is `true` if and only if `y.equals(x)` is `true`

# The `equals()` contract: Transitivity

3. transitive :
   - if a first object is equal to a second, and the second object is equal to a third, then the first object must be equal to the third
   - if `x.equals(y)` is `true`, and `y.equals(z)` is `true`, then `x.equals(z)` must be `true`

# The `equals()` contract: Consistency

4. consistent :
   - repeatedly comparing two objects yields the same result (assuming the state of the objects does not change)

# The `equals()` contract: Non-nullity

5. **`x.equals(null)`** is always **`false`** and never does not throw an exception

# The `equals()` contract and `getClass()`

- using `getClass()` makes it relatively easy to ensure that the `equals()` contract is obeyed
  - e.g., symmetry and transitivity are easy to ensure
- however, using `getClass()` means that your `equals()` method won't work as expected in inheritance hierarchies
  - more on this when we talk about inheritance

# One more thing regarding `equals()`

- if you override `equals()` you must override `hashCode()`
  - otherwise, the hashed containers won't work properly

- we will see how to implement `hashCode()` in the next lecture or so
  - also a discussion about how the hashed containers actually work

# Mutable Classes

# Mutable Classes

- a mutable class can change how its state appears to clients
  - recall that immutable classes are generally easier to implement and use
  - so why would we want a mutable class?
    - because you need a separate immutable object for every value you need to represent
      - example is String concatenation

# Reading a Text File into a String

```
BufferedReader in =
    new BufferedReader(new FileReader(file));
String contents = "";
while (in.ready()) {
  contents = contents + in.readLine();
}
```

creates a new String object
to perform the concatenation
each iteration of the loop

# Reading a Text File into a StringBuilder

```
BufferedReader in =
    new BufferedReader(new FileReader(file));
StringBuilder contents = new StringBuilder();
while (in.ready()) {
  contents.append(in.readLine());
}
```

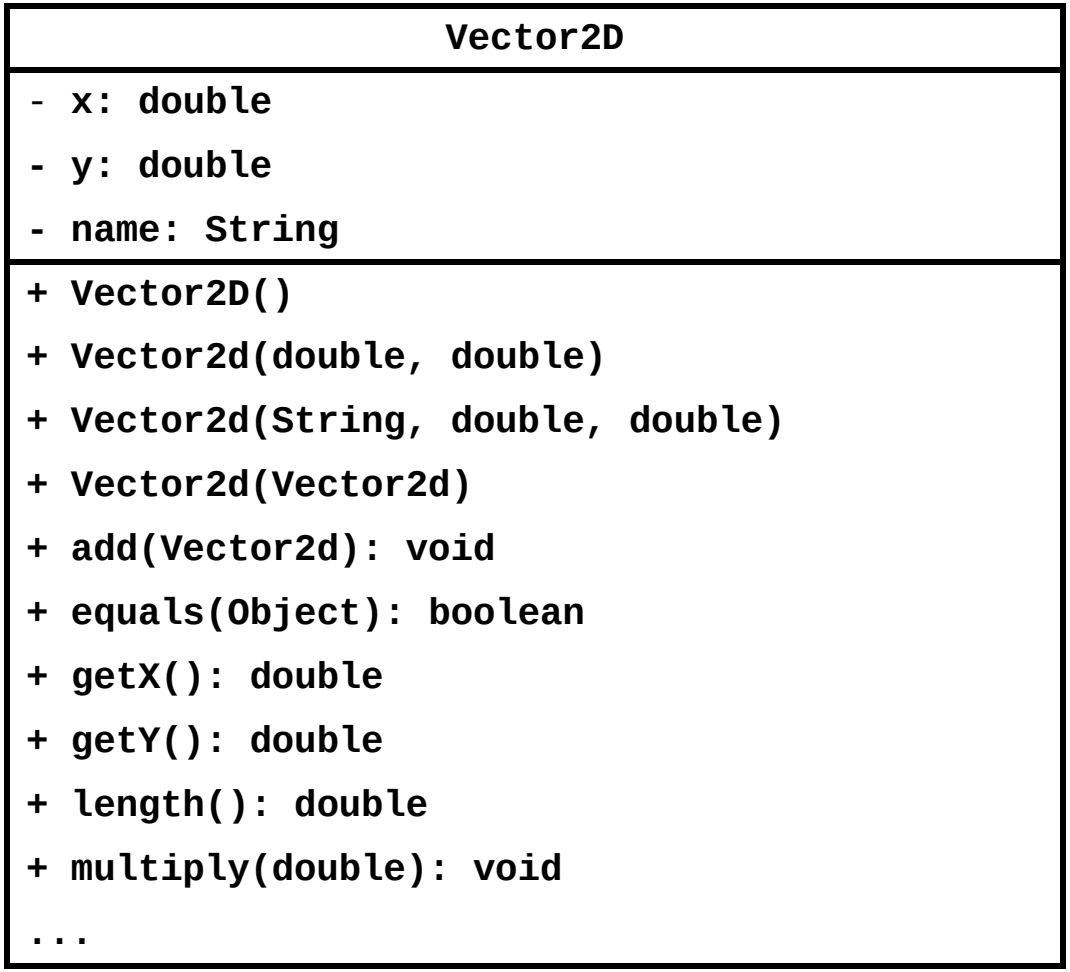
new String not created for each iteration

# Example Mutable class

- we will create a class to represent 2-dimensional vectors

# What Can Mathematical Vectors Do?

- add
- subtract
- multiply by scalar
- set coordinates
- get coordinates
- construct
- equals
- toString



# Constructors

- recall that the role of the constructor is to initialize the attributes of a new object
  - for **`Vector2D`** we need to initialize **`x`**, **`y`**, and **`name`**
- we have 4 overloaded constructors

| |
|---|
| **`Vector2D()`**<br>Create the vector (0, 0) with no name. |
| **`Vector2D(double x, double y)`**<br>Create the vector (x, y) with no name. |
| **`Vector2D(String name, double x, double y)`**<br>Create the vector (x, y) with the given name. |
| **`Vector2D(Vector2D other)`**<br>Create a new vector that is equal to the given vector. |

# Constructors

```
public Vector2D() {
  this.x = 0;
  this.y = 0;
  this.name = null;
}

public Vector2D(double x, double y) {
  this.x = x;
  this.y = y;
  this.name = null;
}
```

# Constructors

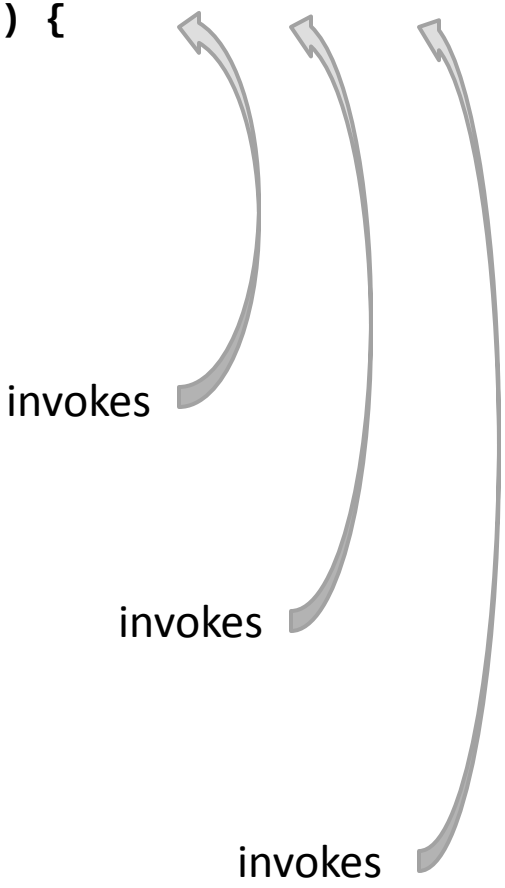
```
public Vector2D(String name, double x, double y) {
  this.x = x;
  this.y = y;
  this.name = name;
}

public Vector2D(Vector2D other) {
  this.x = other.x;
  this.y = other.y;
  this.name = other.name;
}
```

# Avoiding Code Duplication

- notice that the constructor bodies are almost identical to each other
- whenever you see duplicated code you should consider moving the duplicated code into a method
- in this case, one of the constructors already does everything we need to implement the other constructors…

# Constructors

```
public Vector2D(double x, double y, String name) {
  this.x = x;
  this.y = y;
  this.name = name;
}

public Vector2D() {
  this(0, 0, null);
}

public Vector2D(double x, double y) {
  this(x, y, null);
}

public Vector2D(Vector2D other) {
  this(other.x, other.y, other.name);
}
```



# Constructor Chaining

- when a constructor invokes another constructor it is called *constructor chaining*
- to invoke a constructor in the same class you use the **`this`** keyword
  - if you do this then it must occur on the first line of the constructor body

# Accessor Methods

- recall that accessor methods return information about the state of the object
  - for **`Vector2D`** we need to return information about **`x`**, **`y`**, and **`name`**
- we have 3 accessor methods

| |
|---|
| **`double getX()`**<br>Get the x coordinate of the vector. |
| **`double getY()`**<br>Get the y coordinate of the vector. |
| **`String getName()`**<br>Get the name of the vector. |

# Accessor Methods

```
public double getX() {
  return this.x;
}

public double getY() {
  return this.y;
}

public double getName() {
  return this.name;
}
```

# Mutator Methods

- recall that mutator methods allow a client to manipulate the state of the object
  - for **`Vector2D`** we need to allow the client to manipulate **`x`**, **`y`**, and **`name`**

# Mutator Methods

- we have 5 mutator methods

| |
|---|
| **`void setX(double x)`**<br>Set the x coordinate of the vector. |
| **`void setY(double y)`**<br>Set the y coordinate of the vector. |
| **`void setName(String name)`**<br>Set the name of the vector. |
| **`void set(double x, double y)`**<br>Set the x and y coordinate of the vector |
| **`void set(String name, double x, double y)`**<br>Set the name, x, and y coordinate of the vector |

# `setX()`, `setY()`, and `set()`

```
public void setX(double x) {
  this.x = x;
}

public void setY(double y) {
  this.y = y;
}

public void setName(String name) {
  this.name = name;
}

public void set(double x, double y) {
  this.setX(x);
  this.setY(y);
}

public void set(String name, double x, double y) {
  this.setName(name);
  this.set(x, y);
}
```

# Equals

- recall that most value type classes will want their own version of **`equals`**
  - we shall say that two vectors are equal if their **`x`**, and **`y`** coordinates are equal
    - i.e., two vectors might be equal even if their names are different

**`boolean equals(Object obj)`**
Compares two vectors for equality.

# equals()

```
@Override public boolean equals(Object obj)
{
  boolean eq = false;
  if (obj == this) {
    eq = true;
  }




  return eq;
}
```

```
@Override public boolean equals(Object obj)
{
  boolean eq = false;
  if (obj == this) {
    eq = true;
  }
  else if (obj != null && this.getClass() == obj.getClass()) {



  }
  return eq;
}
```

```
@Override public boolean equals(Object obj)
{
  boolean eq = false;
  if (obj == this) {
    eq = true;
  }
  else if (obj != null && this.getClass() == obj.getClass())  {
    Vector2d other = (Vector2d) obj;



  }
  return eq;
}
```

This version works most of the time (except when it doesn't!)

```
@Override public boolean equals(Object obj)
{
  boolean eq = false;
  if (obj == this) {
    eq = true;
  }
  else if (obj != null && this.getClass() == obj.getClass())  {
    Vector2d other = (Vector2d) obj;
    eq = this.getX() == other.getX() &&
         this.getY() == other.getY();
  }
  return eq;
}
```

This version always works.

```
@Override public boolean equals(Object obj)
{
  boolean eq = false;
  if (obj == this) {
    eq = true;
  }
  else if (obj != null && this.getClass() == obj.getClass()) {
    Vector2d other = (Vector2d) obj;
    eq = Double.compare(this.getX(), other.getX()) == 0 &&
         Double.compare(this.getY(), other.getY()) == 0;
  }
  return eq;
}
```

# == vs Double.compare

- the issue here is quite subtle
- if you use == to compare the coordinates then

```
Vector2D u = new Vector2D(0.0 / 0.0, 1.0);  // (NaN, 1.0)
Vector2D v = new Vector2D(u);               // (NaN, 1.0)
boolean eq = u.equals(v);
```

**`eq`** will be **`false`** because **`NaN == NaN`** is always **`false`**

- NaN means "not a number" and is used to represent a mathematically undefined number
  - such as occurs when you divide zero by zero
  - the behavior of NaN is defined in the IEEE 754 standard for floating point arithmetic (i.e., this is not just a Java issue)

# == vs Double.compare

- if you use == to compare the coordinates then all hash based collections and all sets will behave strangely with vectors having NaN as a component

```
Set<Vector2D> set = new HashSet<Vector2D>();
Vector2D u = new Vector2D(0.0 / 0.0, 1.0);  // (NaN, 1.0)
Vector2D v = new Vector2D(u);               // (NaN, 1.0)
set.add(u);
set.add(v);
System.out.println(set.size());             // prints 2
```

- sets are supposed to reject duplicate elements but there are 2 identical vectors in **`set`**
  - occurs because **`Set`** uses **`equals`** to check for duplicates

# == vs Double.compare

- if you use **`Double.compare`** to compare the coordinates then

```
Vector2D u = new Vector2D(0.0 / 0.0, 1.0);  // (NaN, 1.0)
Vector2D v = new Vector2D(u);               // (NaN, 1.0)
boolean eq = u.equals(v);
```

**`eq`** will be **`true`** because **`Double.compare`** is implemented to allow for equality of **`NaN`**

- checking for equality of **`NaN`** can be useful when trying to track down errors in computations
- also the hash based collections and sets will work as expected

# == vs Double.compare

- there is a side effect of using **`Double.compare`** to compare the coordinates

```
Vector2D u = new Vector2D(0.0, 1.0);    // (0.0, 1.0)
Vector2D v = new Vector2D(-0.0, 1.0);   // (-0.0, 1.0)
boolean eq = u.equals(v);
```

**`eq`** will be **`false`** because **`Double.compare`** considers 0.0 and -0.0 to be unequal

- can you see how to implement equals to allow for equality of **`NaN`** and equality of 0.0 and -0.0?

# == vs Double.compare

- the real issue here is that floating point arithmetic is tricky and affects every programming language
- a good starting point for learning more about some of the issues involved
  - http://floating-point-gui.de/

# Observe That...

- instead of directly using the fields, we use accessor methods where possible
  - this reduces code duplication, especially if accessing an field requires a lot of code
  - this gives us the possibility to change the representation of the fields in the future
    - as long as we update the accessor methods (but we would have to do that anyway to preserve the API)
    - for example, instead of two attributes **`x`** and **`y`**, we might want to use an array or some sort of **`Collection`**

- the notes [notes 2.3.1] call this *delegating to accessors*

# Observe That...

- instead of directly modifying the attributes, we use mutator methods where possible
  - this reduces code duplication, especially if modifying an attribute requires a lot of code
  - this gives us the possibility to change the representation of the attributes in the future
    - as long as we update the mutator methods (but we would have to do that anyway to preserve the API)
  - for example, instead of two attributes `x` and `y`, we might want to use an array or some sort of `Collection`

- the notes [notes 2.3.1] call this *delegating to mutators*

# Things to Think About

- how do you implement **`Vector2D`** using an array to store the coordinates?
- how do you implement **`Vector2D`** using a **`Collection`** to store the coordinates?
- how do you implement **`VectorND`**, an N-dimensional vector?