Polymorphism

Lecture Question

Question: in a package named "oop.electronics", implement the following to expand the FlashLight/BoomBox functionality. Full functionality from the previous lecture question is required (This will be the last Battery question)

- classes Battery, Electronic, BoomBox, and FlashLight as defined in the previous lecture question
- An **object** named UseElectronics with
  - A method named "useAll" that takes a List of Electronics as a parameter and returns Unit
    - Calls the "use" method on all the Electronics in the input list
    - [Notice that the specific method that is called depends on whether the Electronic is a BoomBox or a FlashLight]
  - A method named "swapBatteries" that takes two Electronics as parameters and returns Unit
    - Exchanges the batteries between the two Electronics

Testing: In a package named "tests" create a Scala class named "TestElectronics" as a test suite that tests all the functionality listed above

Lecture Question

Electronics again?

Use all method (useAll)

Use all with the same battery and then put the OG battery back in each?

Overview

- Different behavior based on type

Lecture Question

Objective: Apply polymorphism and method overrides in Scala

Question: [Scala] In a package named "inheritance" create an abstract class named "Animal" and concrete classes named "Cat" and "Dog". **Create an object named "Park"**:

Animal: A constructor that takes a String called name (Do not use either val or var. It will be declared in the base classes); An abstract method named sound that takes no parameters and returns a String

- **Override toString to return the name of this Animal**

Cat: Inherent Animal; A constructor that take a String called name as a value (use val to declare name); Override sound() to return "meow"

Dog: Inherent Animal; A constructor that take a String called name as a value (use val to declare name); Override sound() to return "woof"

Park:

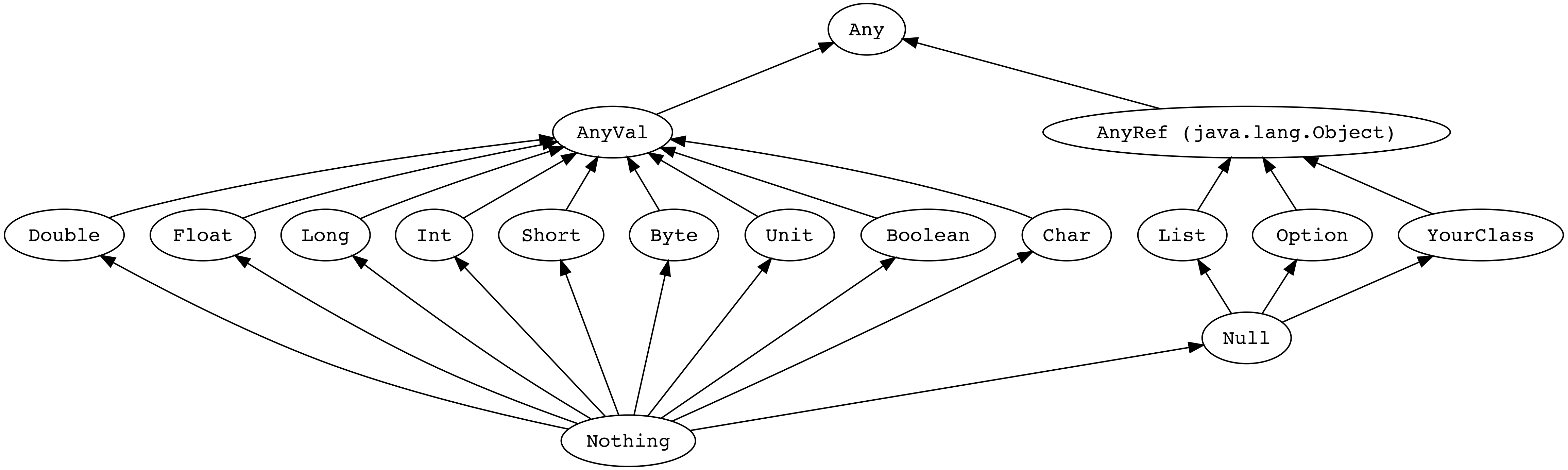
- **A method named "animals" that take no parameters and returns a list of animals containing**
  - **2 dogs with names "Snoopy" and "Finn"**
  - **2 cats with names "Garfield" and "Morris"**
- **A method named "makeSomeNoise" that takes a list of animals as a parameter and returns a list of strings containing the noises from each animal in the input list**

* This question will be open until midnight

Lecture Question

```scala
package tests

import inheritance._
import org.scalatest._

class TestPolymorphism extends FunSuite {

  test("test animal names") {

    val animals: List[Animal] = Park.animals()

    val names: List[String] = animals.map(animal => animal.toString).sorted
    val expectedNames: List[String] = List("Garfield", "Morris", "Snoopy", "Finn").sorted

    assert(names == expectedNames)
  }


  test("test animal noises") {

    val sounds: List[String] = Park.makeSomeNoise(Park.animals()).sorted
    val expectedSounds: List[String] = List("meow", "meow", "woof", "woof").sorted

    assert(sounds == expectedSounds)
  }

}
```

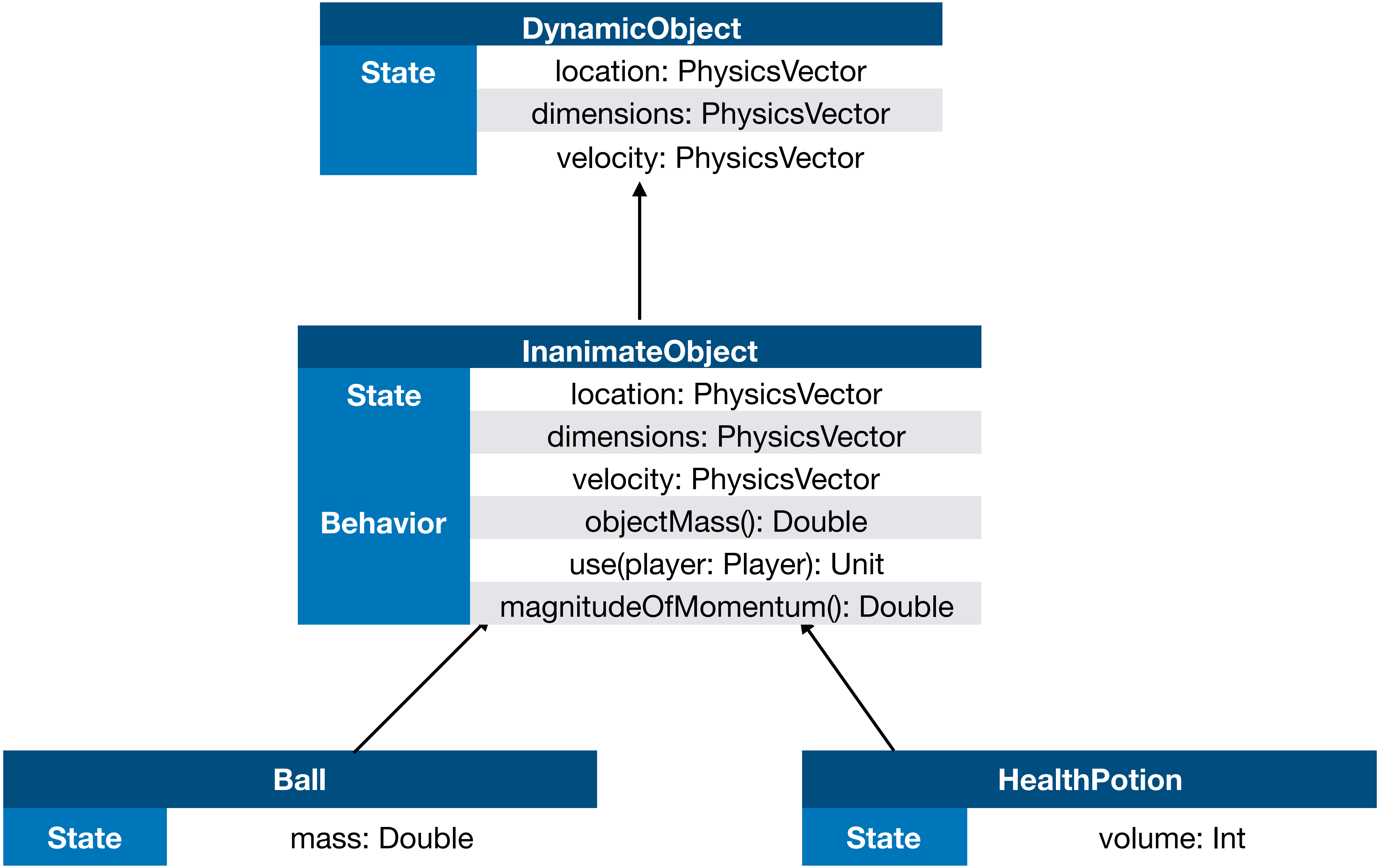
Scala Type Hierarchy



- All objects share Any as their base types
- Classes extending AnyVal will be stored on the **stack**
- Classes extending AnyRef will be stored on the **heap**

https://docs.scala-lang.org/tour/unified-types.html

Recall



DynamicObject

State

location: PhysicsVector

dimensions: PhysicsVector

velocity: PhysicsVector

InanimateObject

State

location: PhysicsVector

dimensions: PhysicsVector

velocity: PhysicsVector

Behavior

objectMass(): Double

use(player: Player): Unit

magnitudeOfMomentum(): Double

Ball

State

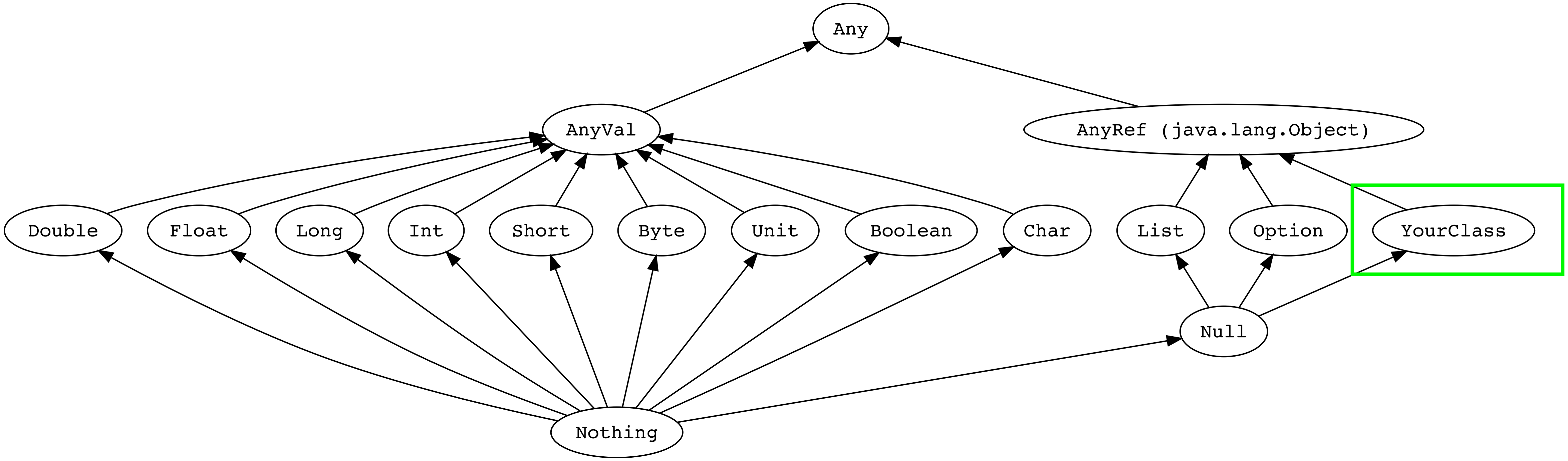
mass: Double

HealthPotion

State

volume: Int

Scala Type Hierarchy



- Classes you define extend AnyRef by default
- HealthPotion has 6 different types

```
val potion1: HealthPotion = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
val potion2: InanimateObject = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
val potion3: DynamicObject = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
val potion4: GameObject = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
val potion5: AnyRef = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
val potion6: Any = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
```

https://docs.scala-lang.org/tour/unified-types.html

Polymorphism

- HealthPotion has 6 different types
- Polymorphism
  - Poly -> Many
  - Morph -> Forms
  - Polymorphism -> Many Forms
- Can store values in variables of any of their types

```
val potion1: HealthPotion = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
val potion2: InanimateObject = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
val potion3: DynamicObject = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
val potion4: GameObject = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
val potion5: AnyRef = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
val potion6: Any = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
```

Polymorphism

- Can only access state and behavior defined in variable type
- Defined magnitudeOfMomentum in InanimateObject
- HealthPotion inherited magnitudeOfMomentum when it extended InanimateObject
- DynamicObject has no such method
    - Even when potion3 stores a reference to a HealthPotion object it cannot access magnitudeOfMomentum

```
val potion1: HealthPotion = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
val potion2: InanimateObject = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
val potion3: DynamicObject = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
val potion4: GameObject = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
val potion5: AnyRef = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
val potion6: Any = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)

potion1.magnitudeOfMomentum()
potion2.magnitudeOfMomentum()
potion3.magnitudeOfMomentum() // Does not compile
```

Polymorphism

- Why use polymorphism if it restricts functionality?
    - Simplify other classes
- Player has 2 methods
    - One to use a ball
    - One to use a potion
- Each item the Player can use will need another method in the Player class
- Tedious to expand game

```
class Player(var location: PhysicsVector,
             var dimensions: PhysicsVector,
             var velocity: PhysicsVector,
             var orientation: PhysicsVector,
             val maxHealth: Int,
             val strength: Int) {

  var health: Int = maxHealth

  def useBall(ball: Ball): Unit = {
    ball.use(this)
  }

  def useHealthPotion(potion: HealthPotion): Unit = {
    potion.use(this)
  }
}
```

Polymorphism

- Write functionality using the common base type
- The use method is part of InanimateObject
- Can't access any Ball or HeathPotion specific functionality
    - Any state/behavior needed by Player must be in the InanimateObject class

```
abstract class InanimateObject(
               location: PhysicsVector,
               velocity: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

}
```

```
class Player(var location: PhysicsVector,
             var dimensions: PhysicsVector,
             var velocity: PhysicsVector,
             var orientation: PhysicsVector,
             val maxHealth: Int,
             val strength: Int) {

  var health: Int = maxHealth

  def useBall(ball: Ball): Unit = {
    ball.use(this)
  }

  def useHealthPotion(potion: HealthPotion): Unit = {
    potion.use(this)
  }
}
```

```
class Player(var location: PhysicsVector,
             var dimensions: PhysicsVector,
             var velocity: PhysicsVector,
             var orientation: PhysicsVector,
             val maxHealth: Int,
             val strength: Int) {

  var health: Int = maxHealth

  def useItem(item: InanimateObject): Unit = {
    item.use(this)
  }

}
```

Polymorphism

- We can call useItem with any object that extends InanimateObject as an argument
- The useItem method will have different effects depending on the type of its parameter
  - Different implementations of use will be called
- Adding new object types to our game does not require changing the Player class!
  - Test Player once
  - Without polymorphism we'd have to update and test the Player class for every new object type added to the game

```scala
abstract class InanimateObject(
         location: PhysicsVector,
         velocity: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

}
```

```scala
class Player(var location: PhysicsVector,
             var dimensions: PhysicsVector,
             var velocity: PhysicsVector,
             var orientation: PhysicsVector,
             val maxHealth: Int,
             val strength: Int) {

  var health: Int = maxHealth

  def useItem(item: InanimateObject): Unit = {
    item.use(this)
  }

}
```

```scala
val ball: Ball = new Ball(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 5)
val potion: HealthPotion = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 5)

val player1: Player = new Player(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), new
PhysicsVector(), 20, 12)

player1.useItem(ball)
player1.useItem(potion)
```

Polymorphism

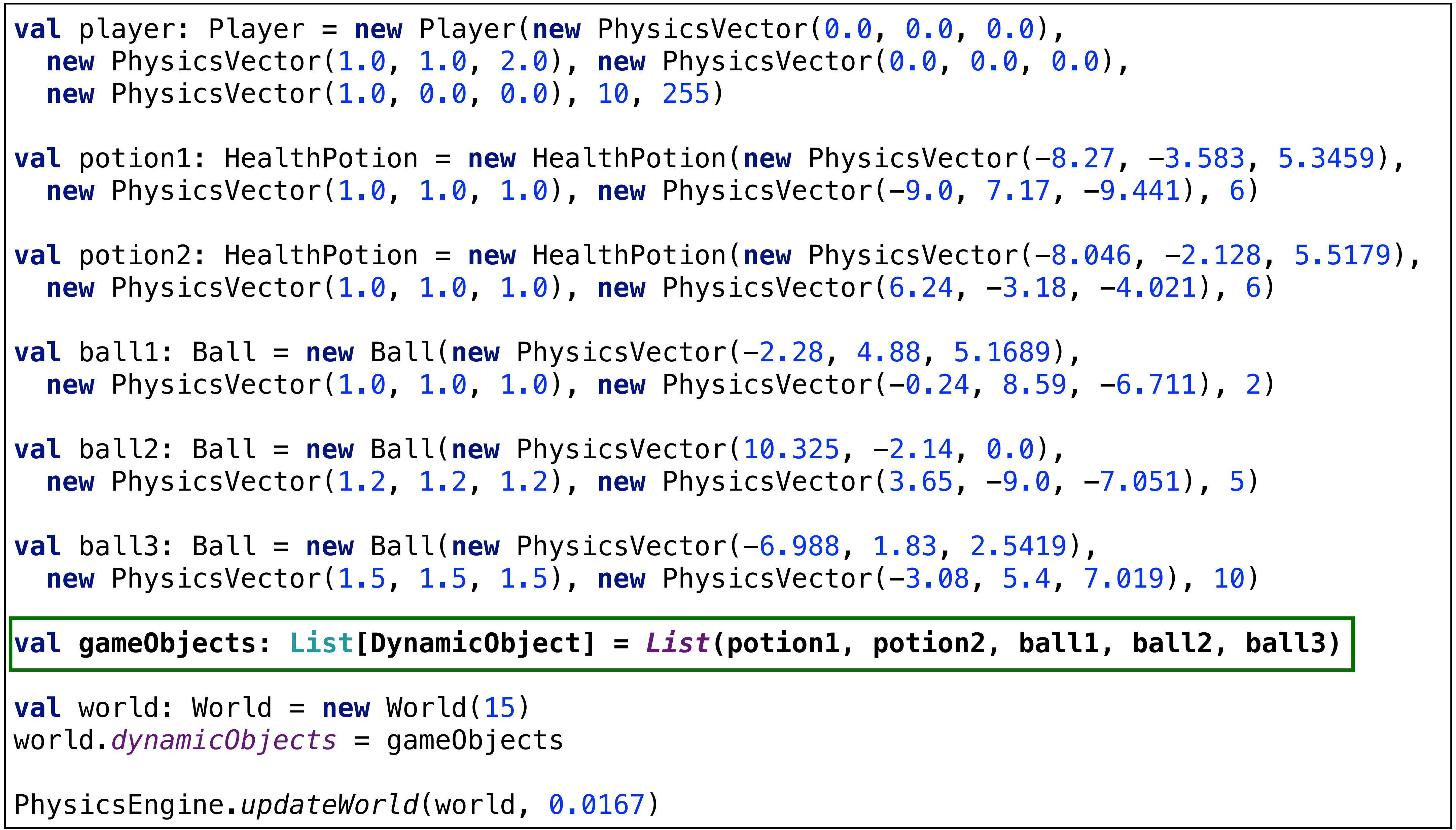
- We can also make our player be a DynamicObject

```
class Player(var location: PhysicsVector,
             var dimensions: PhysicsVector,
             var velocity: PhysicsVector,
             var orientation: PhysicsVector,
             val maxHealth: Int,
             val strength: Int) {

  var health: Int = maxHealth

  def useItem(item: InanimateObject): Unit = {
    item.use(this)
  }

}
```

```
class Player(location: PhysicsVector,
             dimensions: PhysicsVector,
             _velocity: PhysicsVector,
             var orientation: PhysicsVector,
             val maxHealth: Int,
             val strength: Int) extends DynamicObject(location, dimensions) {

  this.velocity = _velocity
  var health: Int = maxHealth

  def useItem(item: InanimateObject): Unit = {
    item.use(this)
  }

}
```

Polymorphism

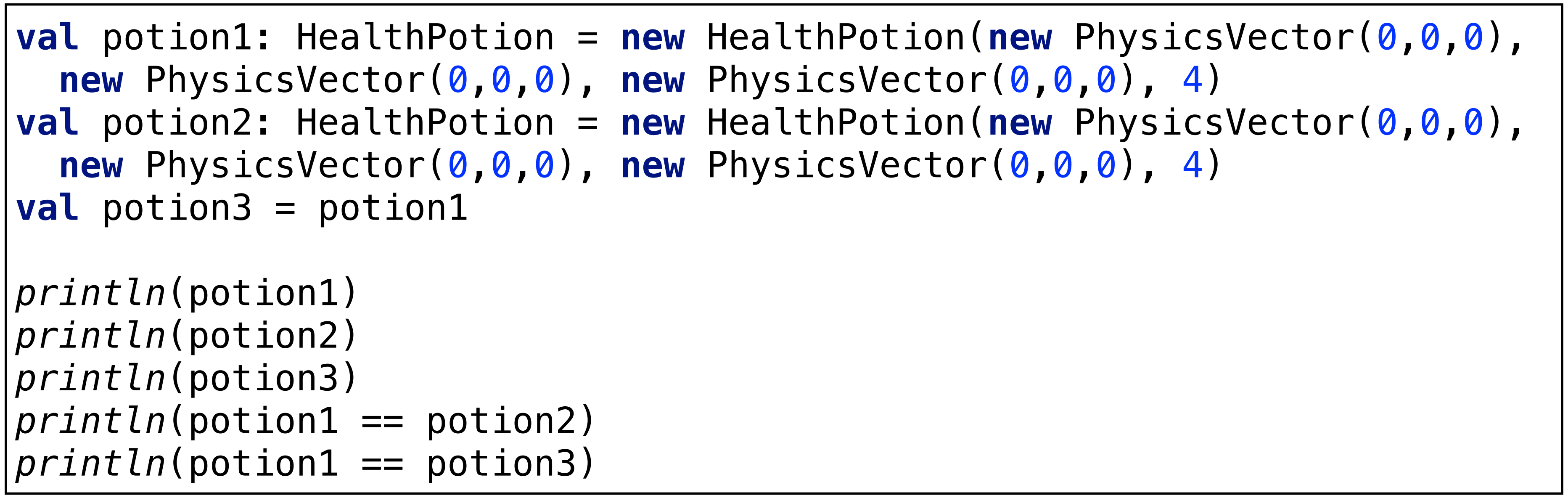
- With polymorphism, we can mix types in data structures
    - Something we took for granted in Python/JavaScript
- PhysicsEngine.updateWorld does not care about the types in world.object
    - As long as they all have DynamicObject as a superclass



```scala
val player: Player = new Player(new PhysicsVector(0.0, 0.0, 0.0),
  new PhysicsVector(1.0, 1.0, 2.0), new PhysicsVector(0.0, 0.0, 0.0),
  new PhysicsVector(1.0, 0.0, 0.0), 10, 255)

val potion1: HealthPotion = new HealthPotion(new PhysicsVector(-8.27, -3.583, 5.3459),
  new PhysicsVector(1.0, 1.0, 1.0), new PhysicsVector(-9.0, 7.17, -9.441), 6)

val potion2: HealthPotion = new HealthPotion(new PhysicsVector(-8.046, -2.128, 5.5179),
  new PhysicsVector(1.0, 1.0, 1.0), new PhysicsVector(6.24, -3.18, -4.021), 6)

val ball1: Ball = new Ball(new PhysicsVector(-2.28, 4.88, 5.1689),
  new PhysicsVector(1.0, 1.0, 1.0), new PhysicsVector(-0.24, 8.59, -6.711), 2)

val ball2: Ball = new Ball(new PhysicsVector(10.325, -2.14, 0.0),
  new PhysicsVector(1.2, 1.2, 1.2), new PhysicsVector(3.65, -9.0, -7.051), 5)

val ball3: Ball = new Ball(new PhysicsVector(-6.988, 1.83, 2.5419),
  new PhysicsVector(1.5, 1.5, 1.5), new PhysicsVector(-3.08, 5.4, 7.019), 10)

val gameObjects: List[DynamicObject] = List(potion1, potion2, ball1, ball2, ball3)

val world: World = new World(15)
world.dynamicObjects = gameObjects

PhysicsEngine.updateWorld(world, 0.0167)
```

Override

- Functionality is inherited from Any and AnyRef
- println calls an inherited .toString method
    - Converts object to a String with <object_type>@<reference>
- == calls the inherited .equals method
    - returns true only if the two variables refer to the same object in memory

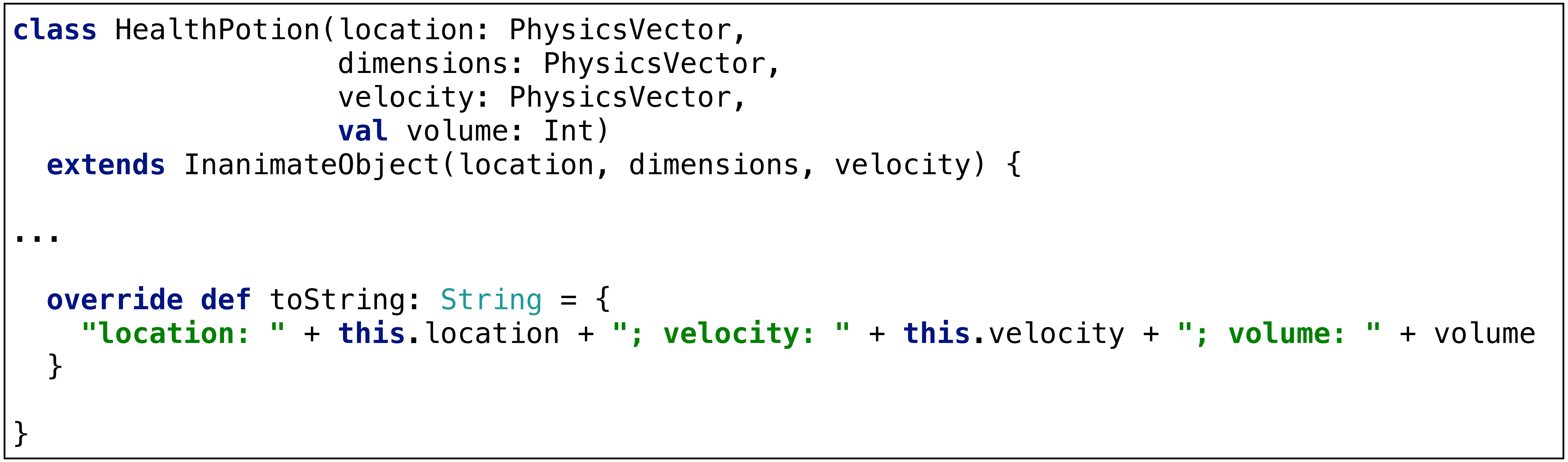


```scala
val potion1: HealthPotion = new HealthPotion(new PhysicsVector(0,0,0),
  new PhysicsVector(0,0,0), new PhysicsVector(0,0,0), 4)
val potion2: HealthPotion = new HealthPotion(new PhysicsVector(0,0,0),
  new PhysicsVector(0,0,0), new PhysicsVector(0,0,0), 4)
val potion3 = potion1

println(potion1)
println(potion2)
println(potion3)
println(potion1 == potion2)
println(potion1 == potion3)
```

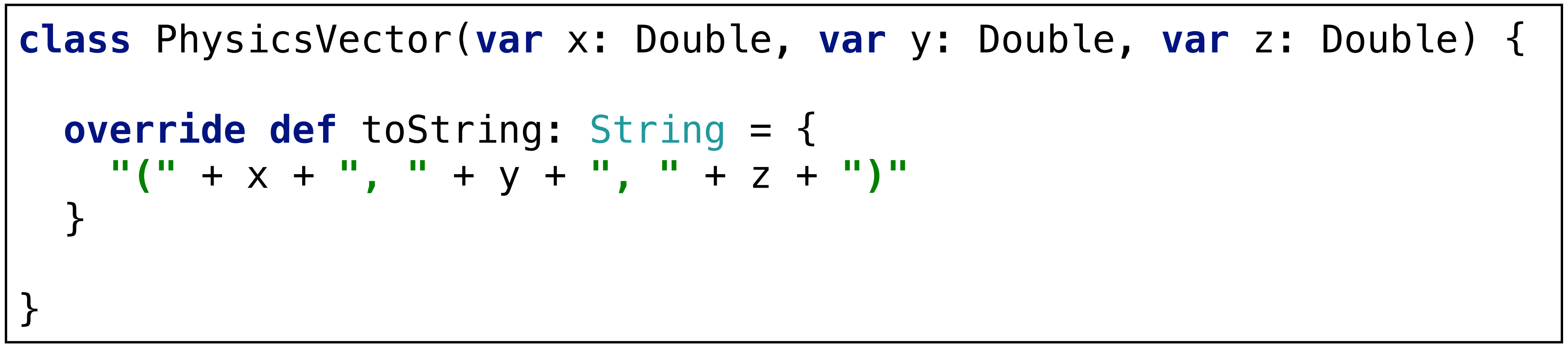
```
week4.oop_physics.with_oop.HealthPotion@17c68925
week4.oop_physics.with_oop.HealthPotion@7e0ea639
week4.oop_physics.with_oop.HealthPotion@17c68925
false
true
```

Override

- We can override this default functionality
- Override toString to return a different string



```
class HealthPotion(location: PhysicsVector,
                   dimensions: PhysicsVector,
                   velocity: PhysicsVector,
                   val volume: Int)
  extends InanimateObject(location, dimensions, velocity) {

...

  override def toString: String = {
    "location: " + this.location + "; velocity: " + this.velocity + "; volume: " + volume
  }

}
```



```
class PhysicsVector(var x: Double, var y: Double, var z: Double) {

  override def toString: String = {
    "(" + x + ", " + y + ", " + z + ")"
  }

}
```

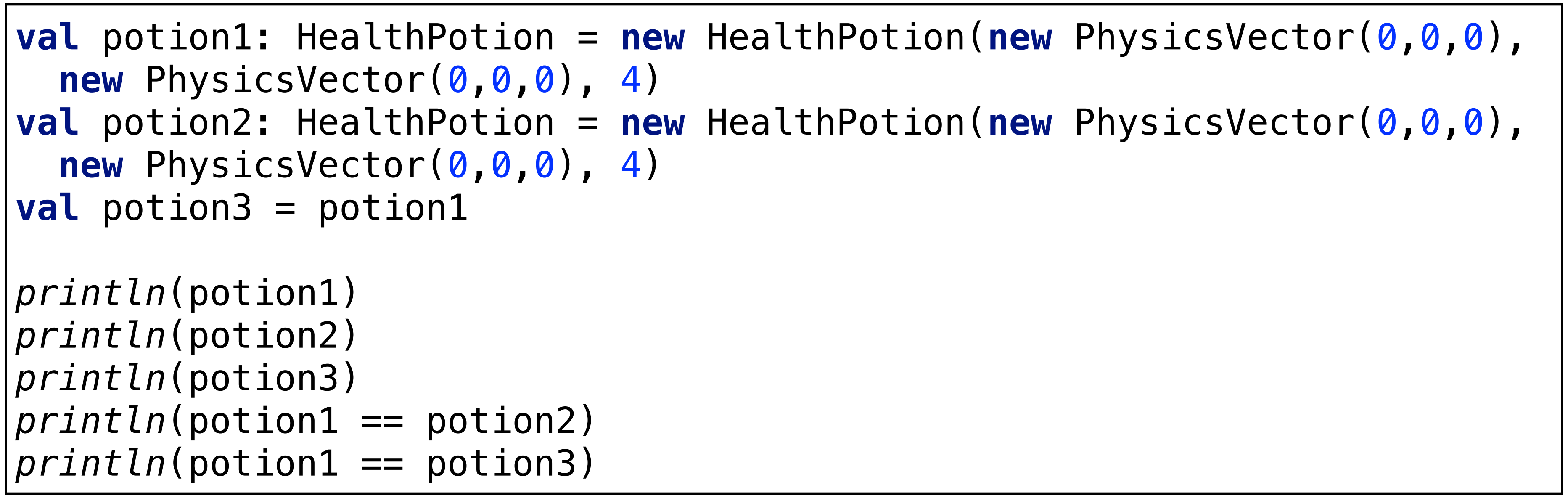
Override

- Override equals to change the definition of equality
- Takes Any as a parameter
- Use match and case to behave differently on different types
- The _ wildcard covers all types not explicitly mentioned
- This method return true when compared to another potion with the same volume, false otherwise

```
class HealthPotion(location: PhysicsVector,
                   dimensions: PhysicsVector,
                   velocity: PhysicsVector,
                   val volume: Int)
  extends InanimateObject(location, dimensions, velocity) {

...

  override def equals(obj: Any): Boolean = {
    obj match {
      case hp: HealthPotion => this.volume == hp.volume
      case _ => false
    }
  }

}
```

Override

- With our overridden methods this code gives very different output



```
val potion1: HealthPotion = new HealthPotion(new PhysicsVector(0,0,0),
  new PhysicsVector(0,0,0), 4)
val potion2: HealthPotion = new HealthPotion(new PhysicsVector(0,0,0),
  new PhysicsVector(0,0,0), 4)
val potion3 = potion1

println(potion1)
println(potion2)
println(potion3)
println(potion1 == potion2)
println(potion1 == potion3)
```

```
location: (0.0, 0.0, 0.0); velocity: (0.0, 0.0, 0.0); volume: 4
location: (0.0, 0.0, 0.0); velocity: (0.0, 0.0, 0.0); volume: 4
location: (0.0, 0.0, 0.0); velocity: (0.0, 0.0, 0.0); volume: 4
true
true
```

Override in Jumper

To create a platform in the jumper game

- Extend JumperObject which extends StaticObject
  - Platforms are now StaticObjects and are compatible with your PhysicsEngine
- Override collideWithDynamicObject to define how an object reacts to a collision with a Platform
  - If the colliding face is the top, the object lands on the Platform

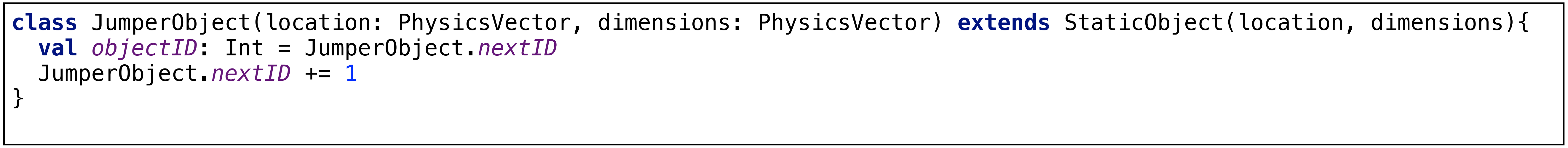
```
class JumperObject(location: PhysicsVector, dimensions: PhysicsVector) extends StaticObject(location, dimensions){
  val objectID: Int = JumperObject.nextID
  JumperObject.nextID += 1
}
```

```
class Platform(location: PhysicsVector, dimensions: PhysicsVector) extends JumperObject(location, dimensions) {

  override def collideWithDynamicObject(otherObject: DynamicObject, face: Integer): Unit = {

    if (face == Face.top) {
      otherObject.velocity.z = 0.0
      otherObject.location.z = this.location.z + this.dimensions.z
      otherObject.onGround()
    }

  }

}
```

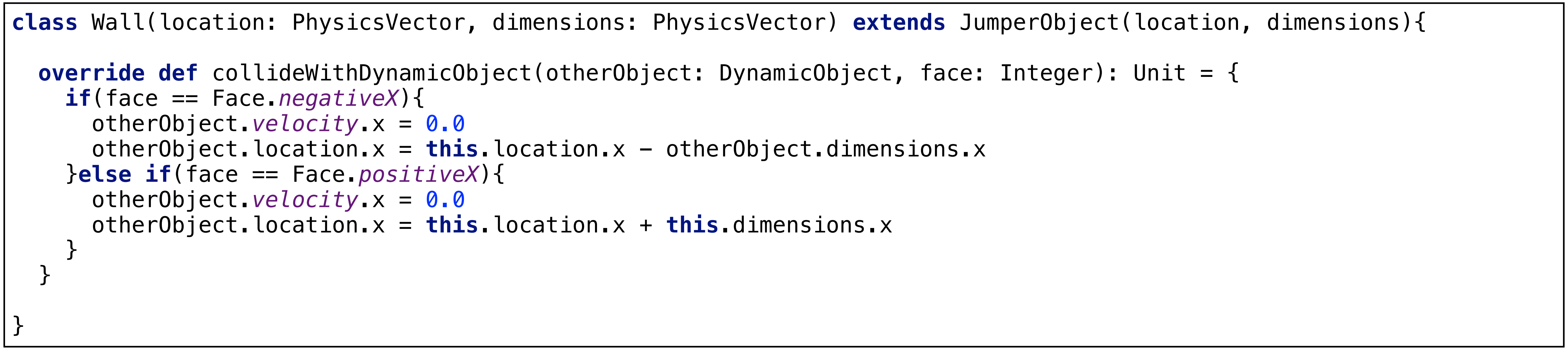
Override in Jumper

- Similar method used to create Walls

- Now all dynamic objects in our game react properly to wall and platform collisions as long as they extend DynamicObject



```scala
class JumperObject(location: PhysicsVector, dimensions: PhysicsVector) extends StaticObject(location, dimensions){
  val objectID: Int = JumperObject.nextID
  JumperObject.nextID += 1
}
```



```scala
class Wall(location: PhysicsVector, dimensions: PhysicsVector) extends JumperObject(location, dimensions){

  override def collideWithDynamicObject(otherObject: DynamicObject, face: Integer): Unit = {
    if(face == Face.negativeX){
      otherObject.velocity.x = 0.0
      otherObject.location.x = this.location.x - otherObject.dimensions.x
    }else if(face == Face.positiveX){
      otherObject.velocity.x = 0.0
      otherObject.location.x = this.location.x + this.dimensions.x
    }
  }

}
```