Inheritance

Lecture Question

Objective: Study the syntax of inheritance in Scala

Question: [Scala] In a package named "inheritance" create an abstract class named "Animal" and concrete classes named "Cat" and "Dog". Implement the following in each class:

Animal:

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

Cat:

- Inherent Animal
- A constructor that take a String called name as a value (use **val** to declare name to make it accessible from outside this class)
- Override sound() to return "meow"

Dog:

- Inherent Animal
- A constructor that take a String called name as a value (use **val** to declare name to make it accessible from outside this class)
- Override sound() to return "woof"

Index	Value
81078	
81079	
81080	
81081	
81082	
81083	
81084	
81085	

Index	Value
42976	
42977	
42978	

Index	Value
27177	
27178	
27179	

Index	Value
59683	
59684	
59685	

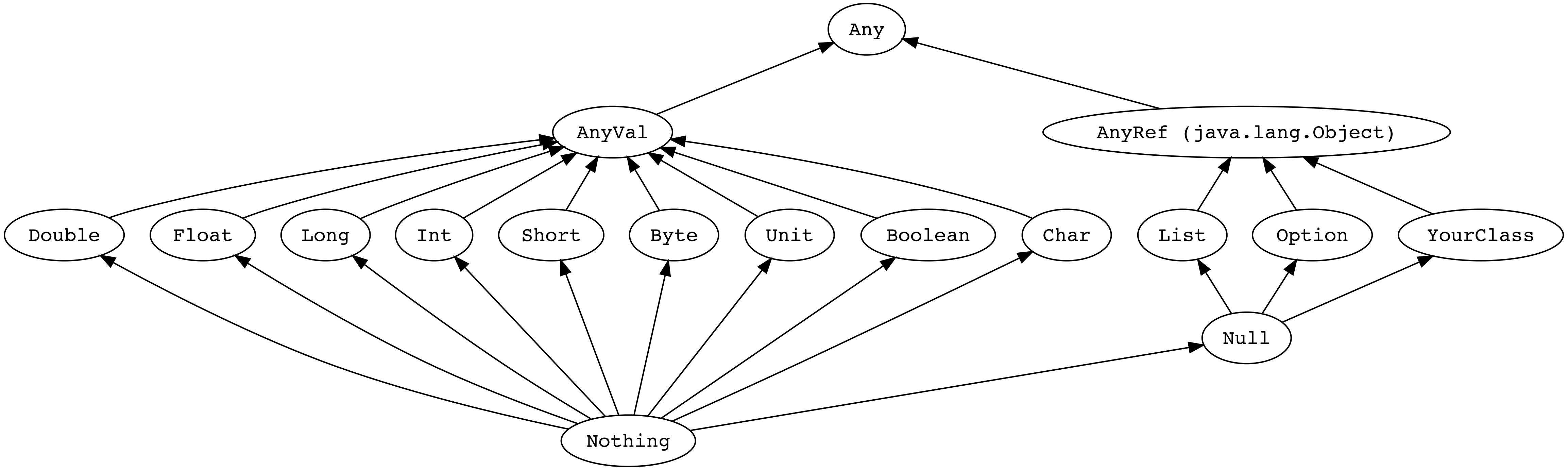
```
  def main(args: Array[String]): Unit = {
    val bird: Bird = new Bird()
    var action: String = "Nothing"
    if(bird.inDanger()){
      val action: String = "Panic!"
    }else{
      val action: String = "Check bird"
    }
    println(action)
    val box: Box = new Box(bird, new Bird())
    if(box.inDanger()){
➔     action = "Stay in the boat"
    }
    println(action)
  }
```

```
class Bird {
  val timesHelpful: Int = 0
  var timesChecked: Int = 0

  def inDanger(): Boolean = {
    timesChecked += 1
    true
  }
}
```

```
class Box(val bird1: Bird, val bird2: Bird) {
  def inDanger(): Boolean = {
    bird1.inDanger() || bird2.inDanger()
  }
}
```

- Sample Quiz question:
  - Draw the stack and heap memory when execution is at the green arrow

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

Overview

- Let's do some world building

- If we're making a game (we're making a game) we'll want various objects that will interact with each other
- We'll setup a simple game where
  - Each player has a set health and strength
  - Players can pick up and throw balls
  - If a player gets hit with a ball, they lose health
  - Players can collect health potions to regain health
- Note: We might not build this full game, but we will build some of the game mechanics

Objects Review

- We'll need different objects for this game
  - Player
  - Ball
  - HealthPotion

Objects Review

Player		
State	location: PhysicsVector	(2.0, -2.0, 2.0)
	dimensions: PhysicsVector	(1.0, 1.0, 2.0)
	velocity: PhysicsVector	(0.0, -1.0, 0.0)
	orientation: PhysicsVector	(0.5, -0.5, 0.0)
	health: Int	17
	maxHealth: Int	20
	strength: Int	25
Behavior	useBall(ball: Ball): Unit	
	useHealthPotion(potion: HealthPotion): Unit	

```scala
object Player {
  var location: PhysicsVector = new PhysicsVector(2.0, -2.0, 2.0)
  var dimensions: PhysicsVector = new PhysicsVector(1.0, 1.0, 2.0)
  var velocity: PhysicsVector = new PhysicsVector(0.0, -1.0, 0.0)
  var orientation: PhysicsVector = new PhysicsVector(0.5, -0.5, 0.0)

  val maxHealth: Int = 20
  val strength: Int = 25

  var health: Int = 17

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

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

Objects Review

Ball		
State	location: PhysicsVector	(1.0, 5.0, 2.0)
	dimensions: PhysicsVector	(1.0, 1.0, 1.0)
	velocity: PhysicsVector	(1.0, 1.0, 10.0)
	mass: Double	5.0
Behavior	used(player: Player): Unit	

```
object Ball {
  var location: PhysicsVector = new PhysicsVector(1.0, 5.0, 2.0)
  var dimensions: PhysicsVector = new PhysicsVector(1.0, 1.0, 1.0)
  var velocity: PhysicsVector = new PhysicsVector(1.0, 1.0, 10.0)
  val mass: Double = 5.0

  def use(player: Player): Unit = {
    this.velocity = new PhysicsVector(
      player.orientation.x * player.strength,
      player.orientation.y * player.strength,
      player.strength
    )
  }
}
```

Objects Review

HealthPotion		
State	location: PhysicsVector	(5.0, 7.0, 0.0)
	dimensions: PhysicsVector	(1.0, 1.0, 1.0)
	velocity: PhysicsVector	(0.0, 0.0, 0.0)
	volume: Int	3
Behavior	use(player: Player): Unit	

```
object HealthPotion {
  var location: PhysicsVector = new PhysicsVector(5.0, 7.0, 0.0)
  var dimensions: PhysicsVector = new PhysicsVector(1.0, 1.0, 1.0)
  var velocity: PhysicsVector = new PhysicsVector(0.0, 0.0, 0.0)
  val volume: Int = 3

  def use(player: Player): Unit = {
    player.health = (player.health + this.volume).min(player.maxHealth)
  }
}
```

Objects Review

- But this is restrictive
- Game can only have one Ball, one HealthPotion, and on Player
- Can play, but not very fun

Player		
State	location: PhysicsVector	(2.0, -2.0, 2.0)
	dimensions: PhysicsVector	(1.0, 1.0, 2.0)
	velocity: PhysicsVector	(0.0, -1.0, 0.0)
	orientation: PhysicsVector	(0.5, -0.5, 0.0)
	health: Int	17
	maxHealth: Int	20
	strength: Int	25
Behavior	useBall(ball: Ball): Unit	
	useHealthPotion(potion: HealthPotion): Unit	

Ball		
State	location: PhysicsVector	(1.0, 5.0, 2.0)
	dimensions: PhysicsVector	(1.0, 1.0, 1.0)
	velocity: PhysicsVector	(1.0, 1.0, 10.0)
	mass: Double	5.0
Behavior	used(player: Player): Unit	

HealthPotion		
State	location: PhysicsVector	(5.0, 7.0, 0.0)
	dimensions: PhysicsVector	(1.0, 1.0, 1.0)
	velocity: PhysicsVector	(0.0, 0.0, 0.0)
	volume: Int	3
Behavior	use(player: Player): Unit	

Classes Review

- This is why we use classes
- Classes let us create multiple objects of type Ball, HealthPotion, and Player

Player	
State	location: PhysicsVector
	dimensions: PhysicsVector
	velocity: PhysicsVector
	orientation: PhysicsVector
	health: Int
	maxHealth: Int
	strength: Int
Behavior	useBall(ball: Ball): Unit
	useHealthPotion(potion: HealthPotion): Unit

Ball	
State	location: PhysicsVector
	dimensions: PhysicsVector
	velocity: PhysicsVector
	mass: Double
Behavior	use(player: Player): Unit

HealthPotion	
State	location: PhysicsVector
	dimensions: PhysicsVector
	velocity: PhysicsVector
	volume: Int
Behavior	use(player: Player): Unit

Classes Review

Player	
State	location: PhysicsVector
	dimensions: PhysicsVector
	velocity: PhysicsVector
	orientation: PhysicsVector
	health: Int
	maxHealth: Int
	strength: Int
Behavior	useBall(ball: Ball): Unit
	useHealthPotion(potion: HealthPotion): 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)
  }
}
```

Classes Review

Ball	
State	location: PhysicsVector
	dimensions: PhysicsVector
	velocity: PhysicsVector
	mass: Double
Behavior	use(player: Player): Unit

```
class Ball(var location: PhysicsVector,
           var dimensions: PhysicsVector,
           var velocity: PhysicsVector,
           val mass: Double) {

  def use(player: Player): Unit = {
    this.velocity = new PhysicsVector(
      player.orientation.x * player.strength,
      player.orientation.y * player.strength,
      player.strength
    )
  }

}
```

Classes Review

HealthPotion	
State	location: PhysicsVector
	dimensions: PhysicsVector
	velocity: PhysicsVector
	volume: Int
Behavior	use(player: Player): Unit

```scala
class HealthPotion(var location: PhysicsVector,
                   var dimensions: PhysicsVector,
                   var velocity: PhysicsVector,
                   val volume: Int) {

  def use(player: Player): Unit = {
    player.health = (player.health + this.volume).min(player.maxHealth)
  }

}
```

Classes Review

- Use the class to create multiple objects with different states

Ball	
State	location: PhysicsVector
	dimensions: PhysicsVector
	velocity: PhysicsVector
	mass: Double
Behavior	use(player: Player): Unit

```
var ball1: Ball = new Ball(
  new PhysicsVector(1.0, 5.0, 2.0),
  new PhysicsVector(1.0, 1.0, 1.0),
  new PhysicsVector(1.0, 1.0, 10.0),
  5.0
)
// ball1 stores 54224
```

Ball@54224		
State	location: PhysicsVector	(1.0, 5.0, 2.0)
	dimensions: PhysicsVector	(1.0, 1.0, 1.0)
	velocity: PhysicsVector	(1.0, 1.0, 10.0)
	mass: Double	5.0
Behavior	use(player: Player): Unit	

```
var ball2: Ball = new Ball(
  new PhysicsVector(6.0, -3.0, 2.0),
  new PhysicsVector(1.0, 1.0, 1.0),
  new PhysicsVector(0.0, 4.5, 4.5),
  10.0
)
// ball2 stores 21374
```

Ball@21374		
State	location: PhysicsVector	(6.0, -3.0, 2.0)
	dimensions: PhysicsVector	(1.0, 1.0, 1.0)
	velocity: PhysicsVector	(0.0, 4.5, 4.5)
	mass: Double	10.0
Behavior	use(player: Player): Unit	

Inheritance

- Use inheritance to create classes with different behavior
- Observe: Ball and HealthPotion have a lot in common

Ball	
State	location: PhysicsVector
	dimensions: PhysicsVector
	velocity: PhysicsVector
	mass: Double
Behavior	use(player: Player): Unit

HealthPotion	
State	location: PhysicsVector
	dimensions: PhysicsVector
	velocity: PhysicsVector
	volume: Int
Behavior	use(player: Player): Unit

Inheritance

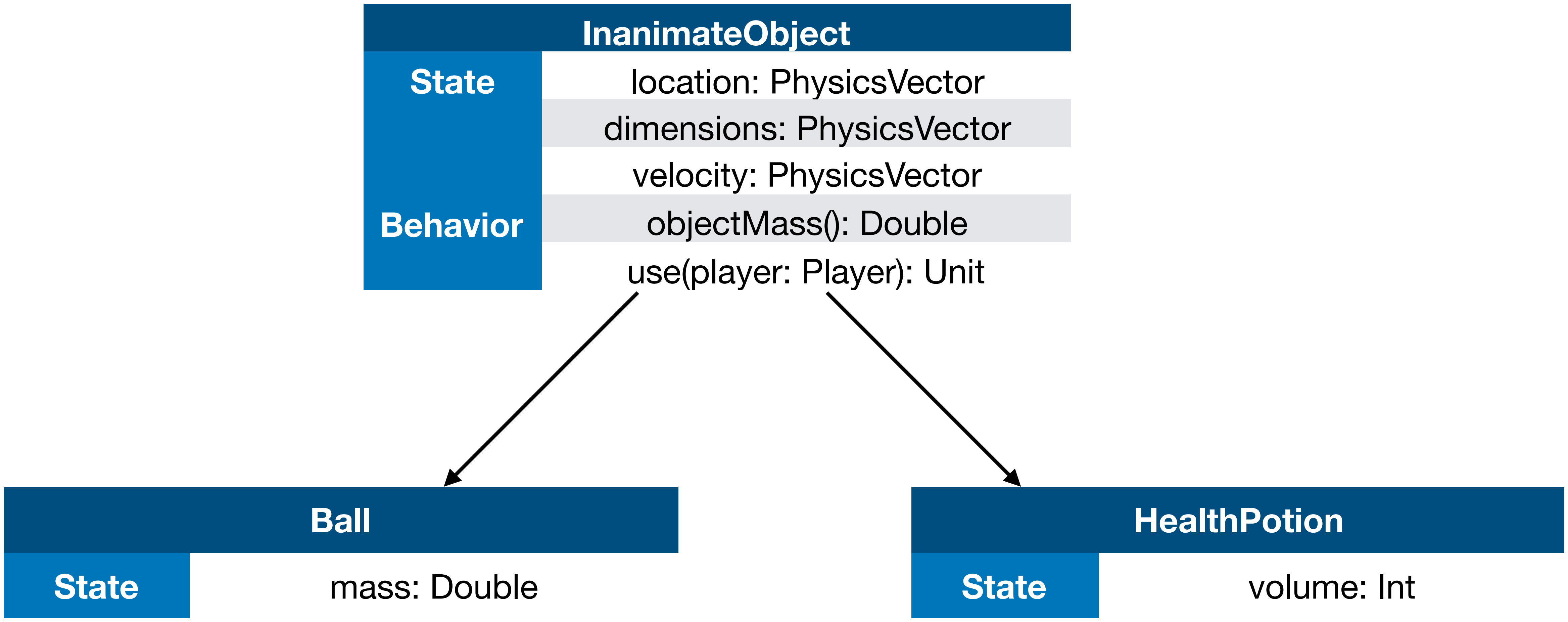
- Can add much more common functionality (that doesn't fit on a slide)
  - Compute mass of a potion based on volume
  - Compute momentum of both types based on mass * velocity
  - Method defining behavior when either hits the ground (bounce or shatter)

Ball	
State	location: PhysicsVector
	dimensions: PhysicsVector
	velocity: PhysicsVector
	mass: Double
Behavior	use(player: Player): Unit

HealthPotion	
State	location: PhysicsVector
	dimensions: PhysicsVector
	velocity: PhysicsVector
	volume: Int
Behavior	use(player: Player): Unit

Inheritance

- Factor out common state and behavior into a new class
- Ball and HealthPotion classes **inherent** the state and behavior of InanimateObject
- Ball and HealthPotion add their specific state and behavior



InanimateObject

State	location: PhysicsVector
	dimensions: PhysicsVector
	velocity: PhysicsVector
Behavior	objectMass(): Double
	use(player: Player): Unit

Ball

State	mass: Double

HealthPotion

State	volume: Int

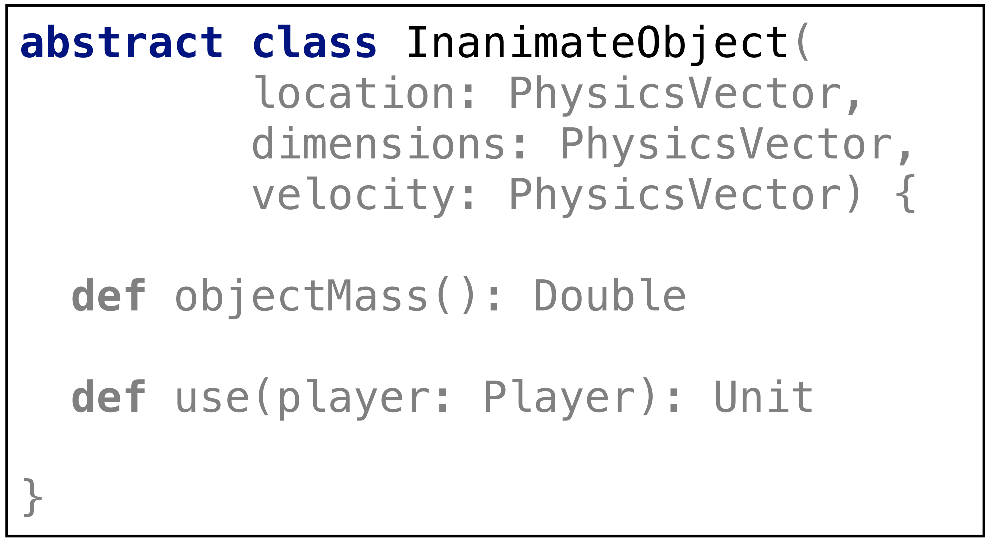
Inheritance

- New class defines what every inheriting class must define
- Any behavior that is to be defined by inheriting classes is declared **abstract**
    - We call this an abstract class
    - Cannot create objects of abstract types
- Inheriting classes will define all abstract behavior
    - We call these concrete classes

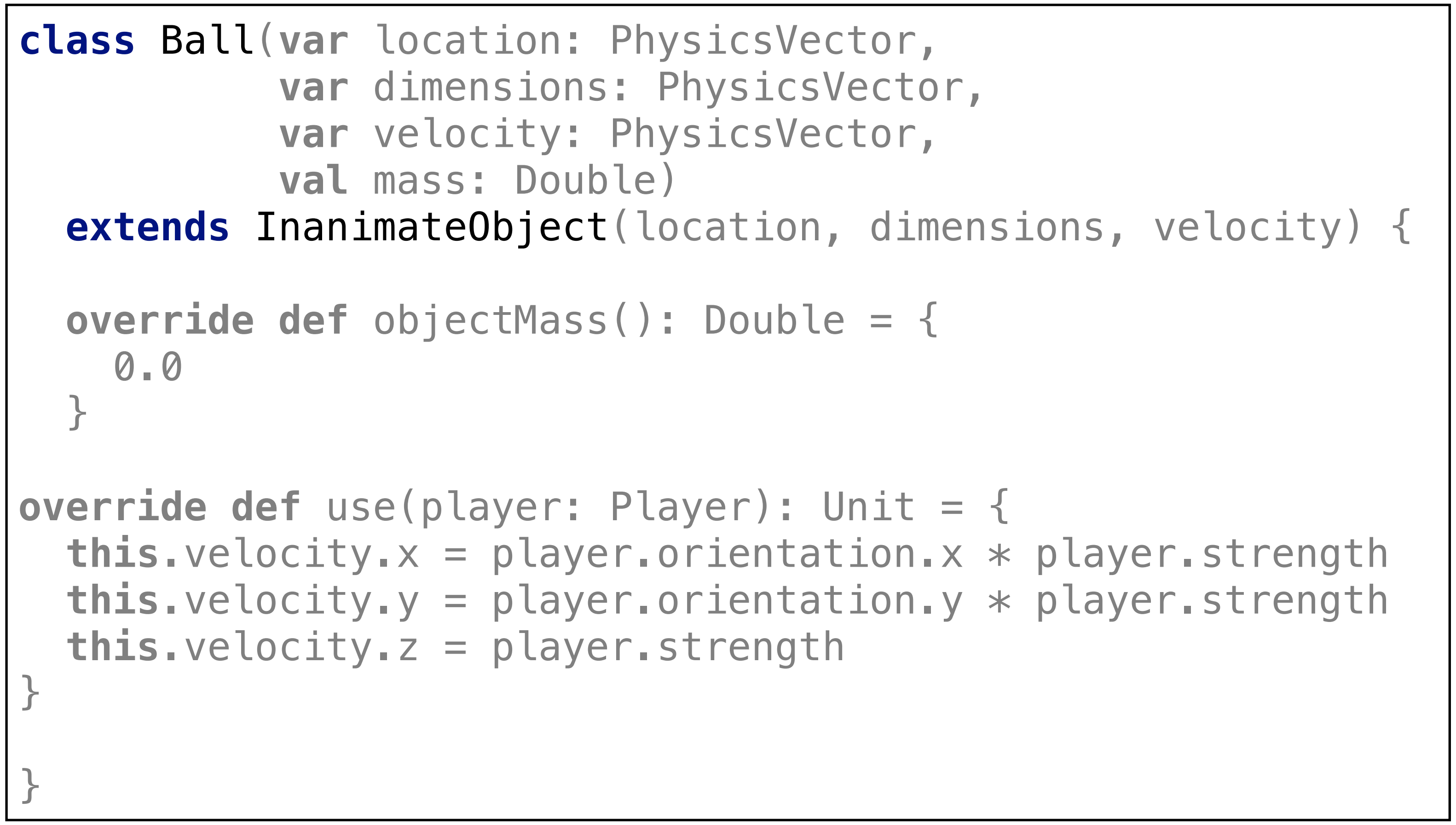
```
abstract class InanimateObject(location: PhysicsVector, dimensions: PhysicsVector,
velocity: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

}
```

Inheritance

- Use the extends keyword to inherent another class
  - Extend the definition of InanimateObject
  - We call InanimateObject the superclass of Ball



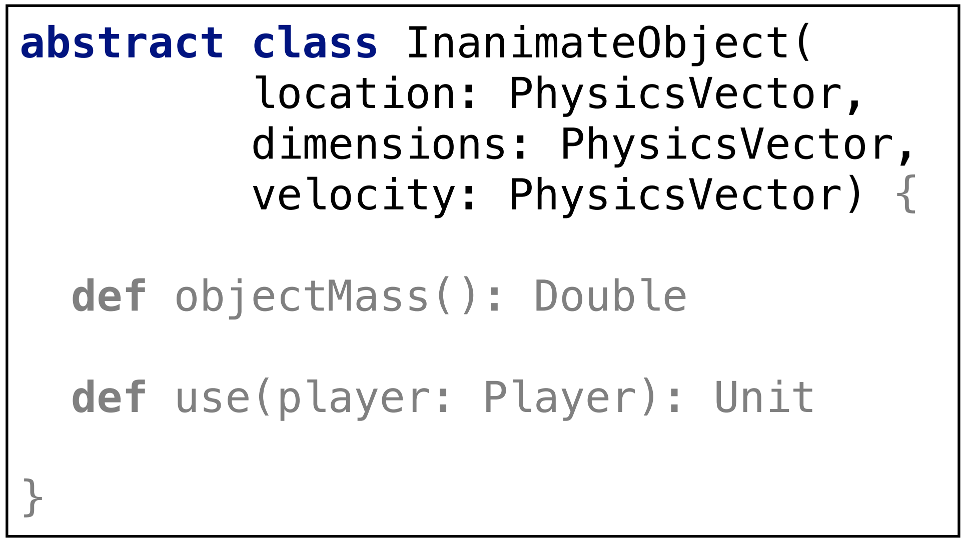
```
abstract class InanimateObject(
         location: PhysicsVector,
         dimensions: PhysicsVector,
         velocity: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

}
```



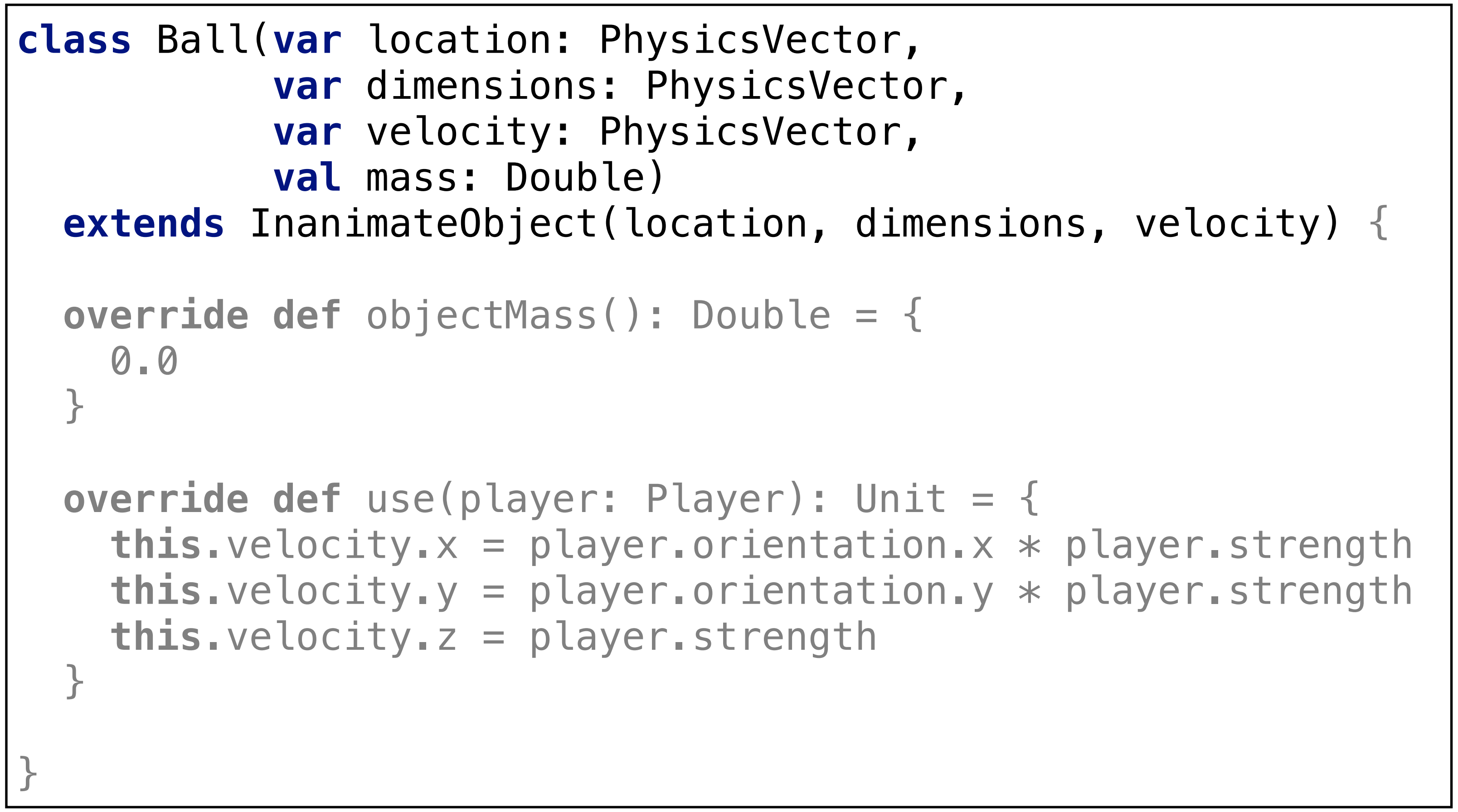
```
class Ball(var location: PhysicsVector,
           var dimensions: PhysicsVector,
           var velocity: PhysicsVector,
           val mass: Double)
  extends InanimateObject(location, dimensions, velocity) {

  override def objectMass(): Double = {
    0.0
  }

override def use(player: Player): Unit = {
  this.velocity.x = player.orientation.x * player.strength
  this.velocity.y = player.orientation.y * player.strength
  this.velocity.z = player.strength
}

}
```

Inheritance

- Ball has it's own constructor
- Ball must call InanimateObject's constructor
- var/val declared in concrete class to make these public



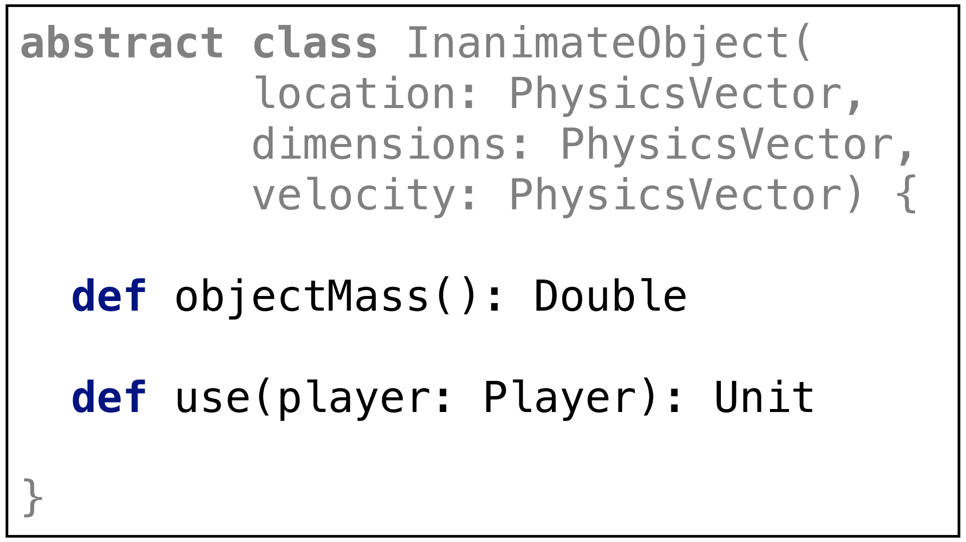
```
abstract class InanimateObject(
         location: PhysicsVector,
         dimensions: PhysicsVector,
         velocity: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

}
```



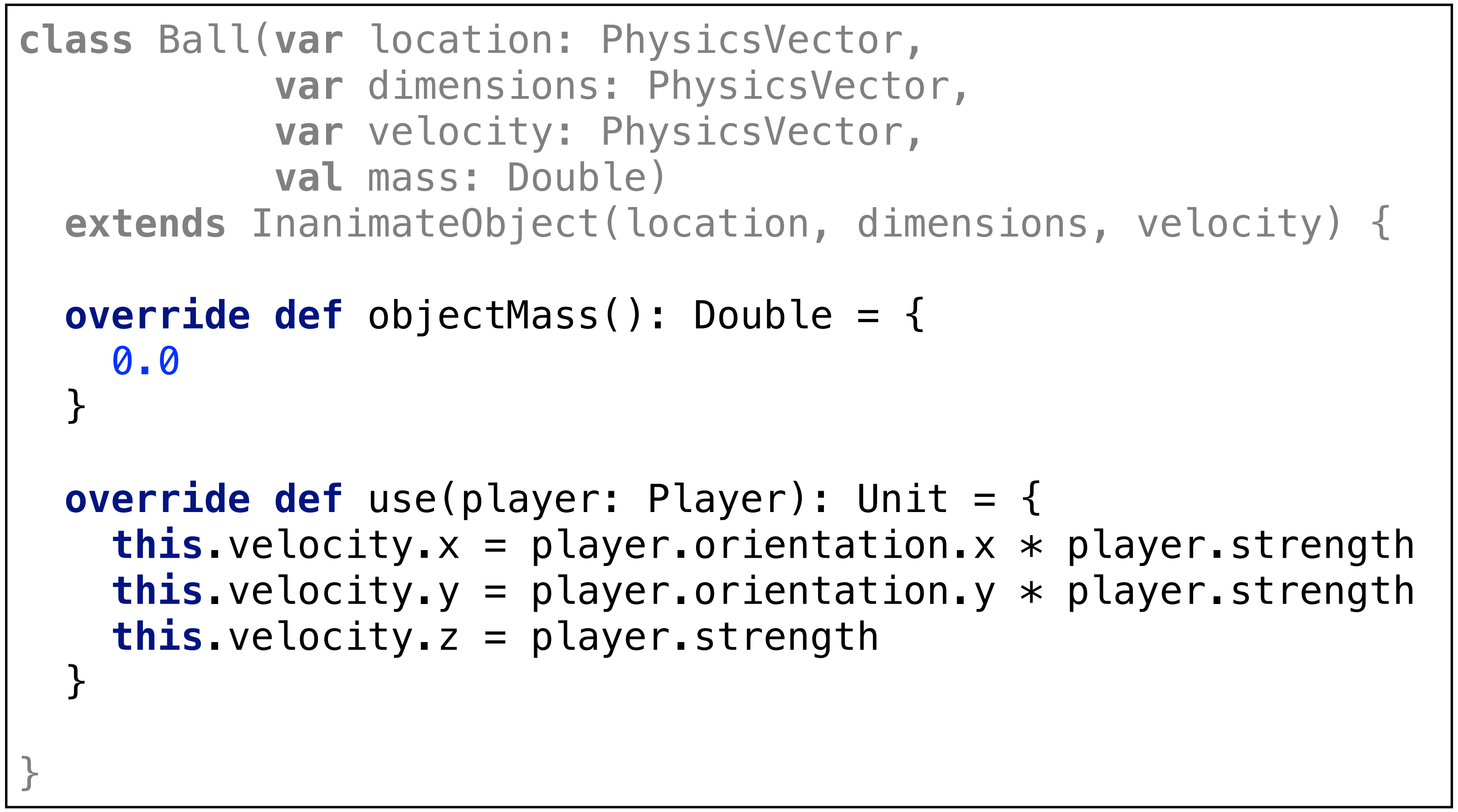
```
class Ball(var location: PhysicsVector,
           var dimensions: PhysicsVector,
           var velocity: PhysicsVector,
           val mass: Double)
  extends InanimateObject(location, dimensions, velocity) {

  override def objectMass(): Double = {
    0.0
  }

  override def use(player: Player): Unit = {
    this.velocity.x = player.orientation.x * player.strength
    this.velocity.y = player.orientation.y * player.strength
    this.velocity.z = player.strength
  }

}
```

Inheritance

- Implement all abstract behavior
- Use the **override** keyword when overwriting behavior from the superclass
- Override all abstract methods with behavior for this class



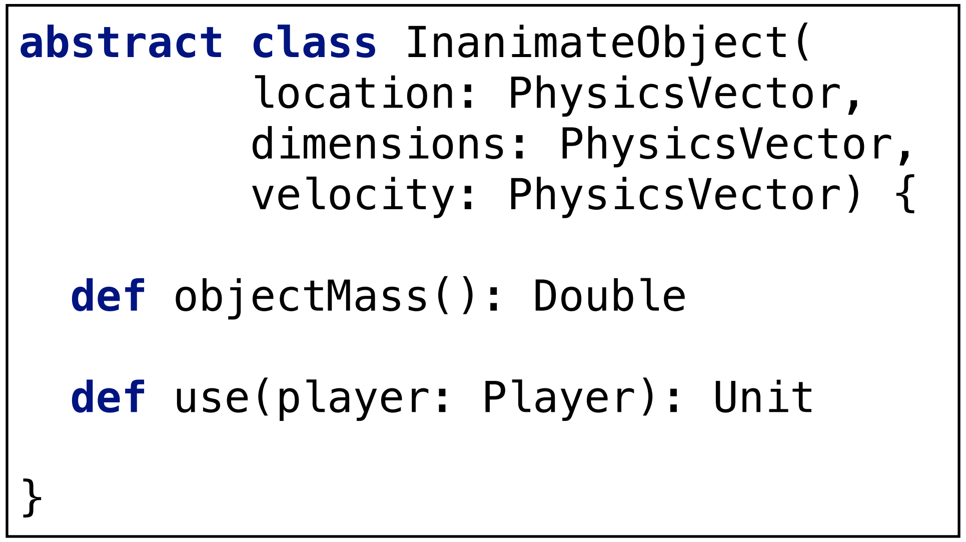
```
abstract class InanimateObject(
         location: PhysicsVector,
         dimensions: PhysicsVector,
         velocity: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

}
```



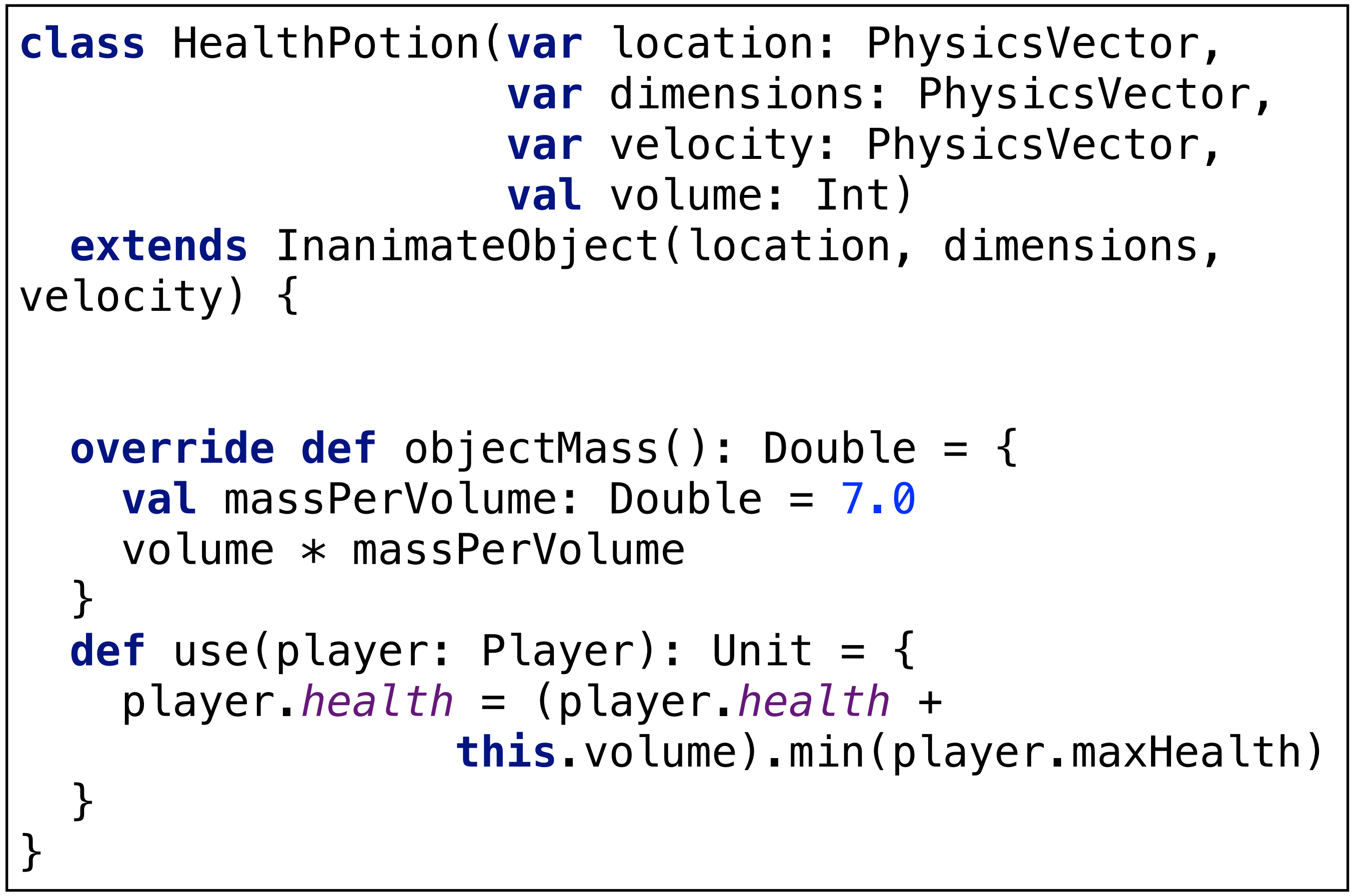
```
class Ball(var location: PhysicsVector,
           var dimensions: PhysicsVector,
           var velocity: PhysicsVector,
           val mass: Double)
  extends InanimateObject(location, dimensions, velocity) {

  override def objectMass(): Double = {
    0.0
  }

  override def use(player: Player): Unit = {
    this.velocity.x = player.orientation.x * player.strength
    this.velocity.y = player.orientation.y * player.strength
    this.velocity.z = player.strength
  }

}
```

Inheritance

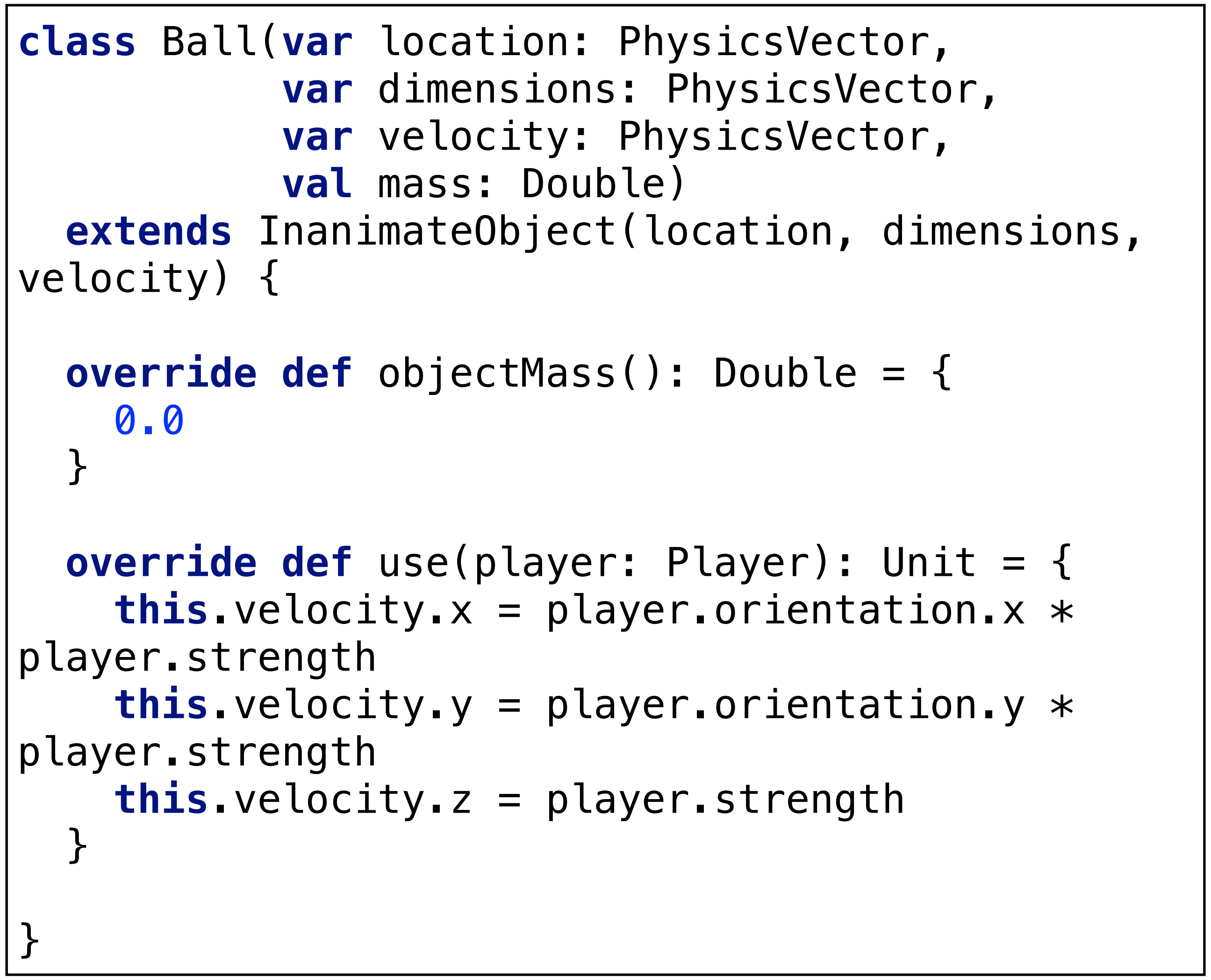
- Define different behavior for each base class
- Define similar types with some difference



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

  def objectMass(): Double

  def use(player: Player): Unit

}
```



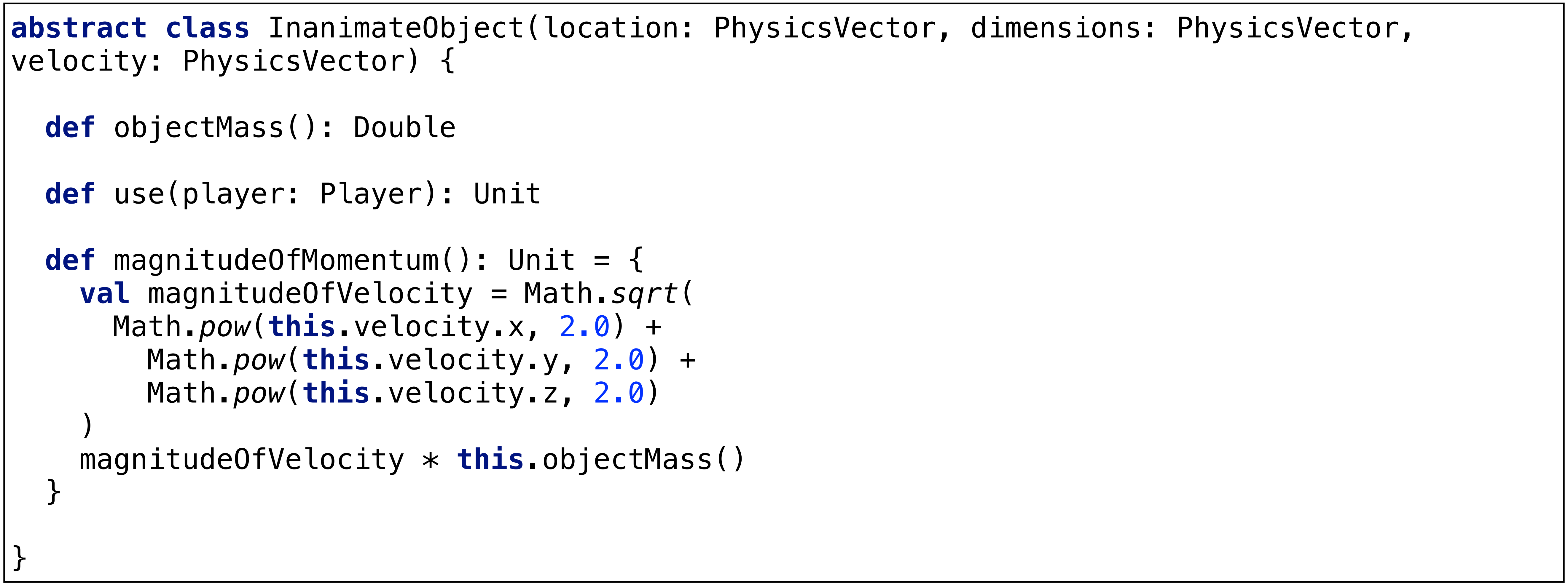
```scala
class HealthPotion(var location: PhysicsVector,
                   var dimensions: PhysicsVector,
                   var velocity: PhysicsVector,
                   val volume: Int)
  extends InanimateObject(location, dimensions,
velocity) {


  override def objectMass(): Double = {
    val massPerVolume: Double = 7.0
    volume * massPerVolume
  }
  def use(player: Player): Unit = {
    player.health = (player.health +
             this.volume).min(player.maxHealth)
  }
}
```



```scala
class Ball(var location: PhysicsVector,
           var dimensions: PhysicsVector,
           var velocity: PhysicsVector,
           val mass: Double)
  extends InanimateObject(location, dimensions,
velocity) {

  override def objectMass(): Double = {
    0.0
  }

  override def use(player: Player): Unit = {
    this.velocity.x = player.orientation.x *
player.strength
    this.velocity.y = player.orientation.y *
player.strength
    this.velocity.z = player.strength
  }

}
```

Inheritance

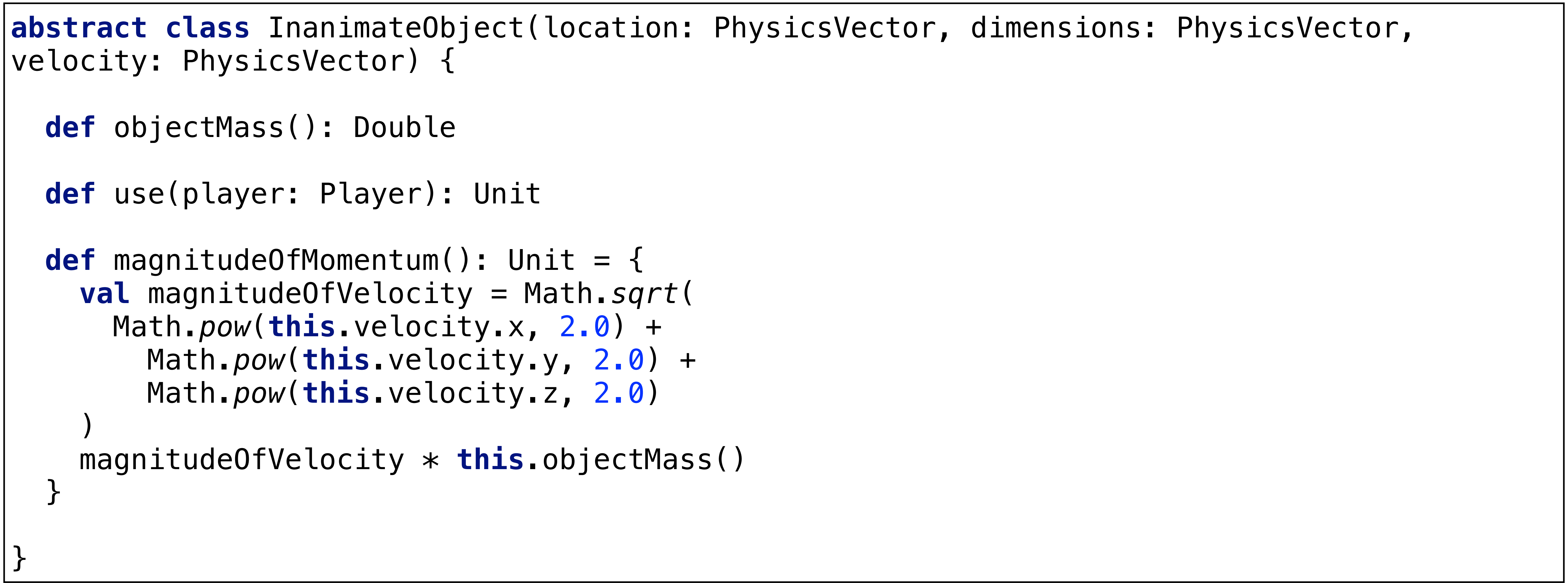
- **OK, BUT Y THO?**
- Add behavior to InanimateObject
- Behavior is added to ALL inheriting classes



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

  def objectMass(): Double

  def use(player: Player): Unit

  def magnitudeOfMomentum(): Unit = {
    val magnitudeOfVelocity = Math.sqrt(
      Math.pow(this.velocity.x, 2.0) +
        Math.pow(this.velocity.y, 2.0) +
        Math.pow(this.velocity.z, 2.0)
    )
    magnitudeOfVelocity * this.objectMass()
  }

}
```

Inheritance

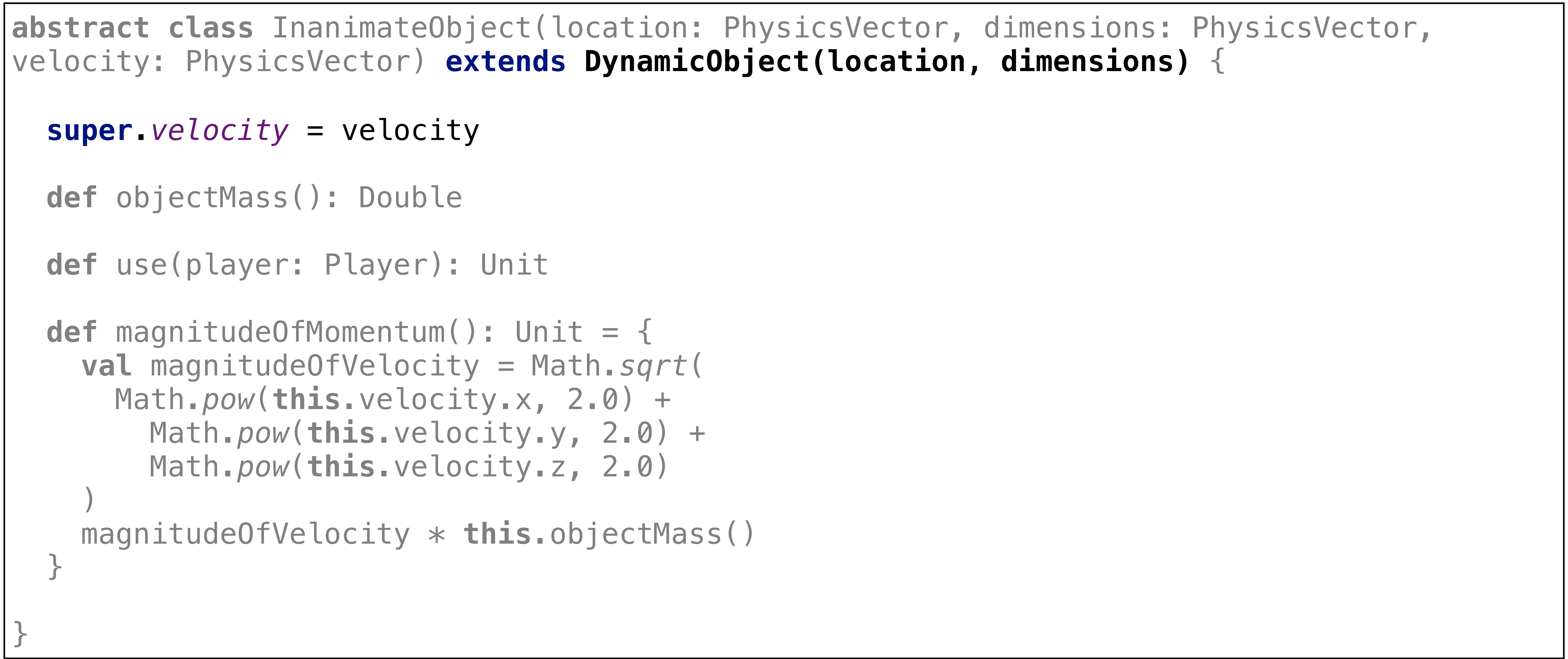
- We may want many, many more subtypes of InanimateObjects in our game
- Any common functionality added to InanimateObject
    - Easy to add functionality to ALL subtypes will very little effort



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

  def objectMass(): Double

  def use(player: Player): Unit

  def magnitudeOfMomentum(): Unit = {
    val magnitudeOfVelocity = Math.sqrt(
      Math.pow(this.velocity.x, 2.0) +
        Math.pow(this.velocity.y, 2.0) +
        Math.pow(this.velocity.z, 2.0)
    )
    magnitudeOfVelocity * this.objectMass()
  }

}
```

Inheritance

- **But wait!**
  - **There's more**



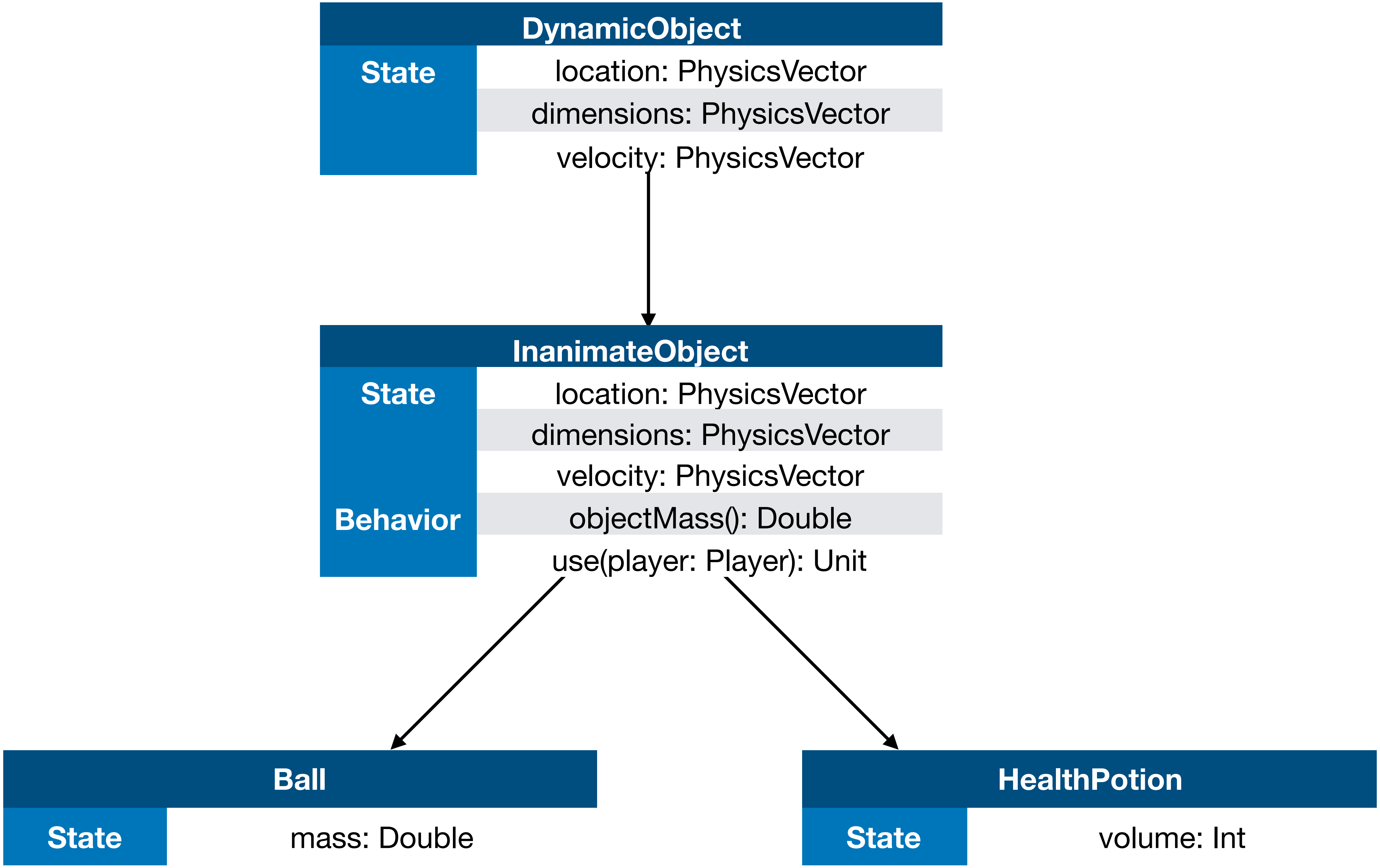
```
abstract class InanimateObject(location: PhysicsVector, dimensions: PhysicsVector,
velocity: PhysicsVector) extends DynamicObject(location, dimensions) {

  super.velocity = velocity

  def objectMass(): Double

  def use(player: Player): Unit

  def magnitudeOfMomentum(): Unit = {
    val magnitudeOfVelocity = Math.sqrt(
      Math.pow(this.velocity.x, 2.0) +
        Math.pow(this.velocity.y, 2.0) +
        Math.pow(this.velocity.z, 2.0)
    )
    magnitudeOfVelocity * this.objectMass()
  }

}
```

Inheritance

- If we want Ball, HealthPotion, and all other InanimateObjects to work with our physics engine
  - Extend DynamicObject!

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

  super.velocity = velocity

  def objectMass(): Double

  def use(player: Player): Unit

  def magnitudeOfMomentum(): Unit = {
    val magnitudeOfVelocity = Math.sqrt(
      Math.pow(this.velocity.x, 2.0) +
        Math.pow(this.velocity.y, 2.0) +
        Math.pow(this.velocity.z, 2.0)
    )
    magnitudeOfVelocity * this.objectMass()
  }

}
```

Inheritance



DynamicObject

State

location: PhysicsVector

dimensions: PhysicsVector

velocity: PhysicsVector

InanimateObject

State

location: PhysicsVector

dimensions: PhysicsVector

velocity: PhysicsVector

Behavior

objectMass(): Double

use(player: Player): Unit

Ball

State

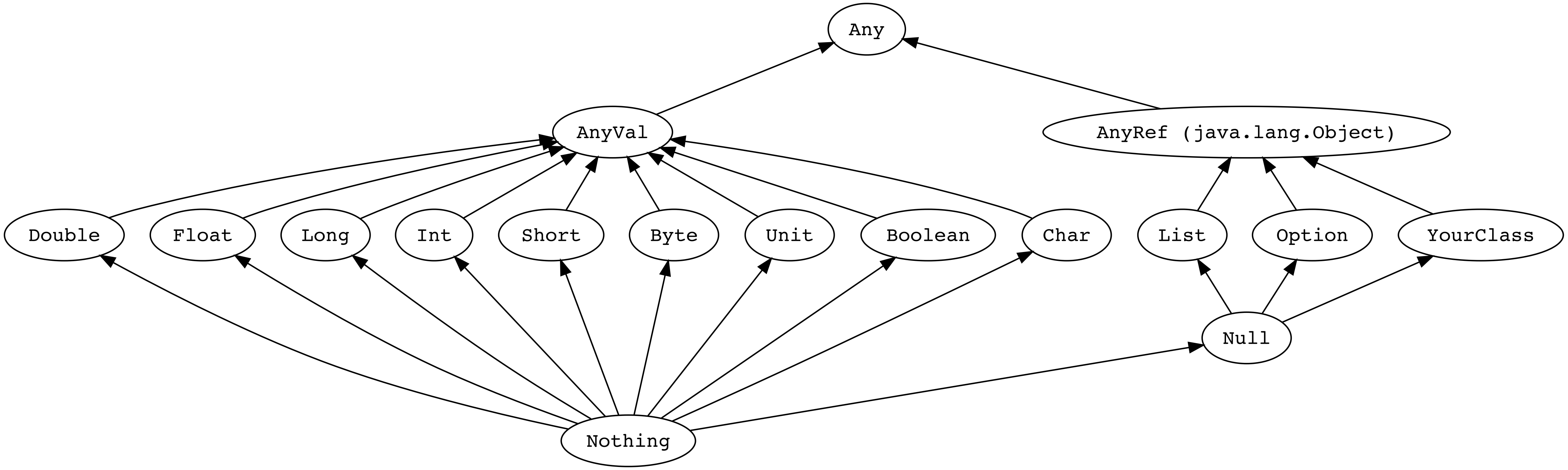
mass: Double

HealthPotion

State

volume: Int

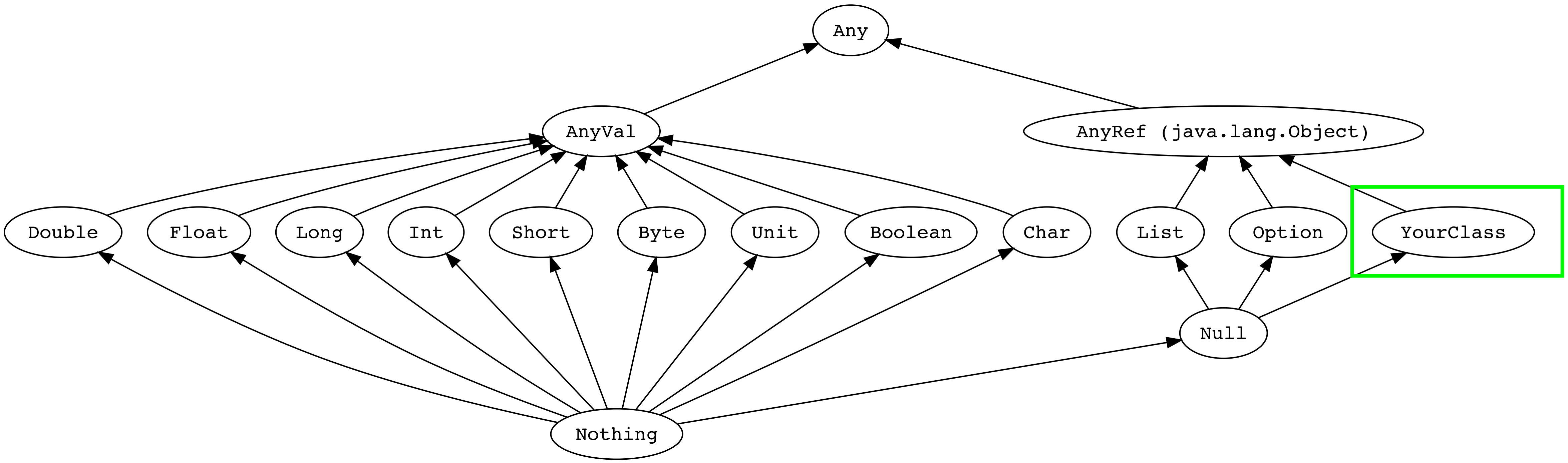
Scala Type Hierarchy



- 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

Scala Type Hierarchy



- Classes you define extend AnyRef by default
- HealthPotion has 5 different types

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

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

Lecture Question

Objective: Study the syntax of inheritance in Scala

Question: [Scala] In a package named "inheritance" create an abstract class named "Animal" and concrete classes named "Cat" and "Dog". Implement the following in each class:

Animal:

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

Cat:

- Inherent Animal
- A constructor that take a String called name as a value (use **val** to declare name to make it accessible from outside this class)
- Override sound() to return "meow"

Dog:

- Inherent Animal
- A constructor that take a String called name as a value (use **val** to declare name to make it accessible from outside this class)
- Override sound() to return "woof"