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M3 (a) – Object State

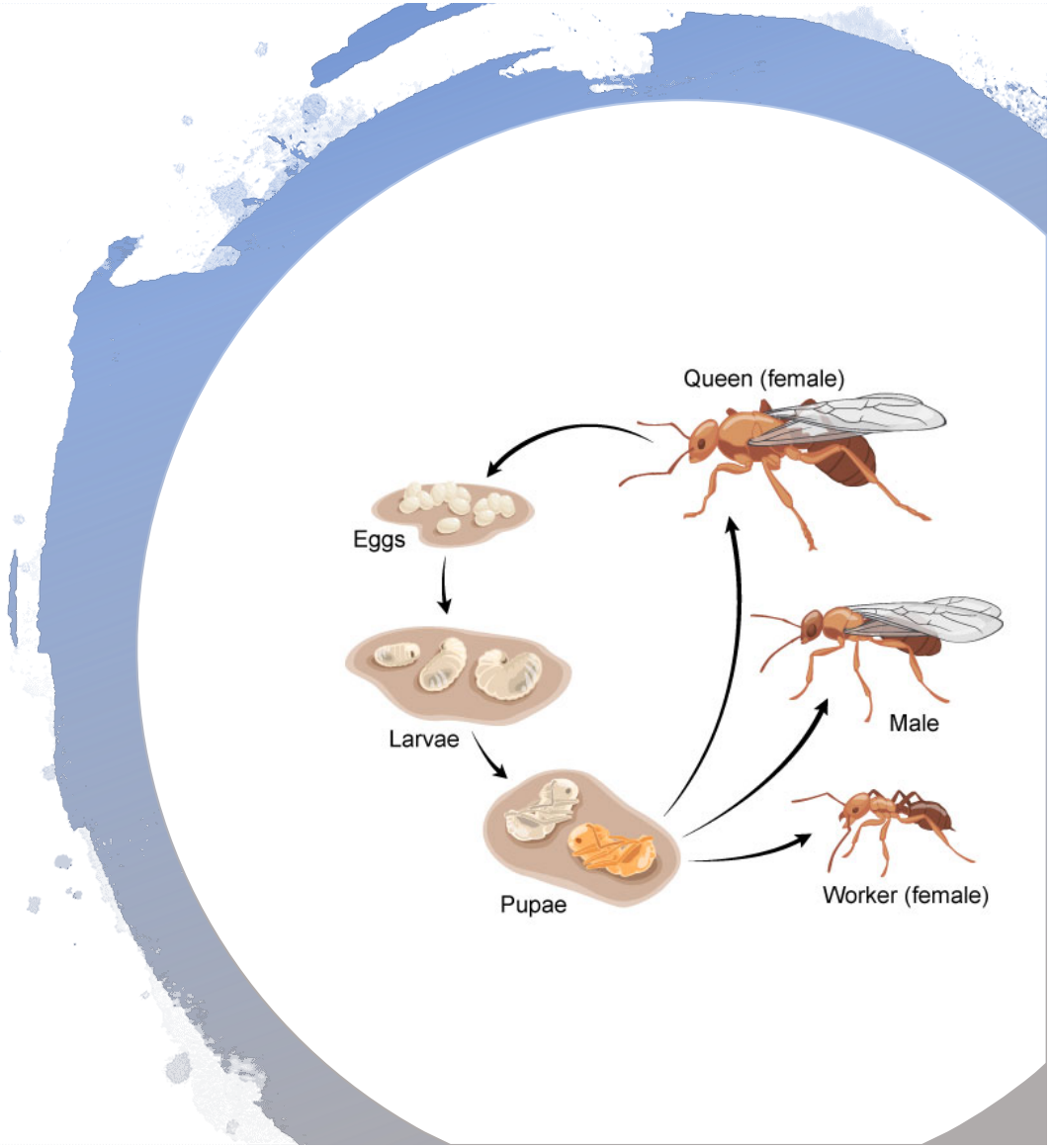


Image Source: https://askabiologist.asu.edu/individual-life-cycle

Objective

- Programming mechanism:

Null references, optional types

- Concepts and Principles:

Object life cycle, object identity and equality

- Design techniques:

State Diagram

Object at Run-time

```
public final class Card
{
    private final Rank aRank;
    private final Suit aSuit;
}
```

{*ACE*, *TWO*, *THREE*, *FOUR*, *FIVE*, *SIX*, *SEVEN*, *EIGHT*, *NINE*, *TEN*, *JACK*, *QUEEN*, *KING*}

{*CLUBS*, *DIAMONDS*, *HEARTS*, *SPADES*}

13x4 possible state

Object at Run-time

Abstract State is needed

```
public class Student {
    // Representation of a word in its original form
    // as in one sentence.
    final private String firstName;
}
```

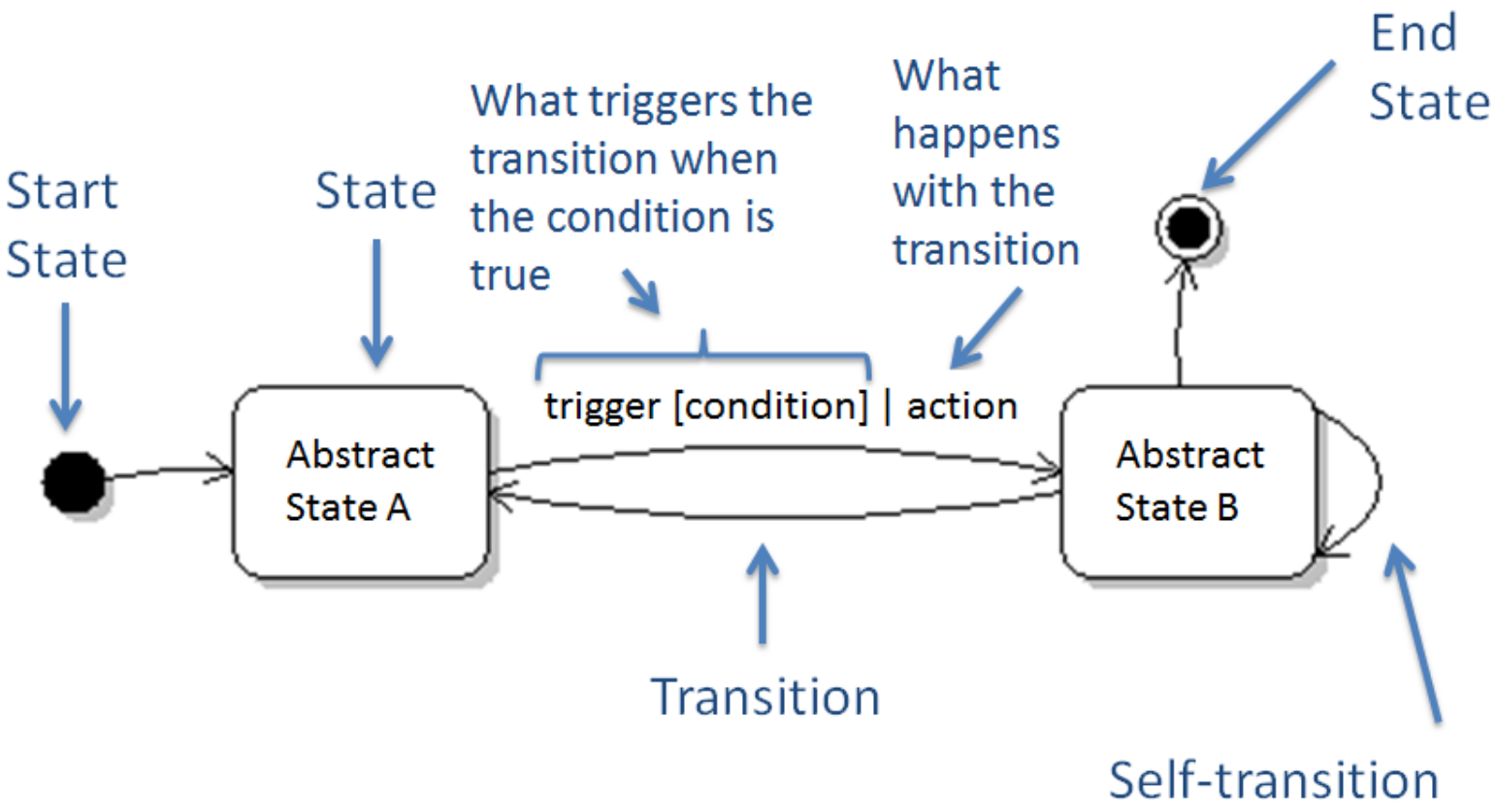
Possible state of the object
(2^31 – 1) X 2^16 !

State Diagram

- Abstract States

- Transitions between states

State Diagram



Activity 1: Sketch the state diagram of `Course`

```
public class Course {

    private String         aID; // e.g. “COMP 303”
    private boolean        aIsActive;
    private int            aCap;
    private List<Student>  aEnrollment;
    private CourseSchedule aSchedule;
```

Design Constructor

- A constructor should fully initialize the object
  - The class invariant should hold
  - Shouldn't need to call other methods to “finish” initialization

Design Field

- Has a value that retains meaning throughout the object's life
- Its state must persist between public method invocations

General Principle

- Minimize the state space of object to what is absolutely necessary
  - It’s impossible to put the object in an invalid of useless state
  - There’s no unnecessary state information

Objective

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Nullability (absence of value)

```
Card card = null;
```

A viable is temporarily un-initialized and will be initialized in a different state.

A viable is incorrectly initialized. The code of initiation is not executed properly.

As a flag that represents the absence of a useful value

Special use.

```
Card.Rank rank = card.getRank();
```

Avoid *null* values when designing classes!

Avoid *null* values when designing classes?

```
public class Course {

    private String aID;
    private boolean aIsActive;
    private int aCap;
    private List<Student> aEnrollment;
    private CourseSchedule aSchedule;

    public Course(String pID, int pCap) {
        aID = pID;
        aCap = pCap;
        aEnrollment = new ArrayList<>();
        aIsActive = false;
    }
```

What about `Schedule`?

It might be a valid state when the class is created but not scheduled.

Avoid *null* values when designing classes?

- Sometimes it’s necessary to model absence of value

Activity 2:

- Discuss your design of the extension of class Card where one instance can also represent a ”Joker”. (Textbook Chatper2 - Exercise#4)

  Note: Joker is special card with no rank and no suit.

- How did you handle the fields of Rank and Suit for “Joker”?

Image source: https://upload.wikimedia.org/wikipedia/commons/6/6f/Joker_Card_Image.jpg

```
public class Card
{
   private Rank aRank;
   private Suit aSuit;
   private boolean aIsJoker;
```

Arbitrary (valid) value for rank and suit?

Add special value for Rank and Suit enums?

java.util.Optional<T>

- A container object which may or may not contain a non-null value.
- If a value is present, isPresent() will return true and get() will return the value.

```
public class Card
{
   private Optional<Rank> aRank;
   private Optional<Suit> aSuit;
   private boolean aIsJoker;
```

```java
public Card(Rank pRank, Suit pSuit)
{
  assert pRank != null && pSuit != null;
  aRank =  Optional.of(pRank);
  aSuit = Optional.of(pSuit);
}

public Card()
{
  aIsJoker = true;
  aRank = Optional.empty();
  aSuit = Optional.empty();
}
```

What about getter methods?

- Return Optional<T> types

- Up-wrap Optional and return T

Go back to the `Course` class

```
public class Course {

    ……

    public Course(String pID, int pCap) {
        aID = pID;
        aCap = pCap;
        aEnrollment = new ArrayList<>();
        aIsActive = false;
        aSchedule = Optional.empty();
    }

    public void setSchedule(CourseSchedule pSchedule) {
        aSchedule =  Optional.of(new CourseSchedule(pSchedule));
    }

    public Optional<CourseSchedule> getSchedule(){
        return aSchedule;
    }
```

Client code of the `Course` class

```
private static void printSchedule(Course pCourse) {
    if(pCourse.getSchedule().isPresent()) {
        CourseSchedule schedule = pCourse.getSchedule().get();
        System.out.println(schedule);
    } else {
        System.out.println("Schedule unavailable.");
    }

}
```

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Object Identity

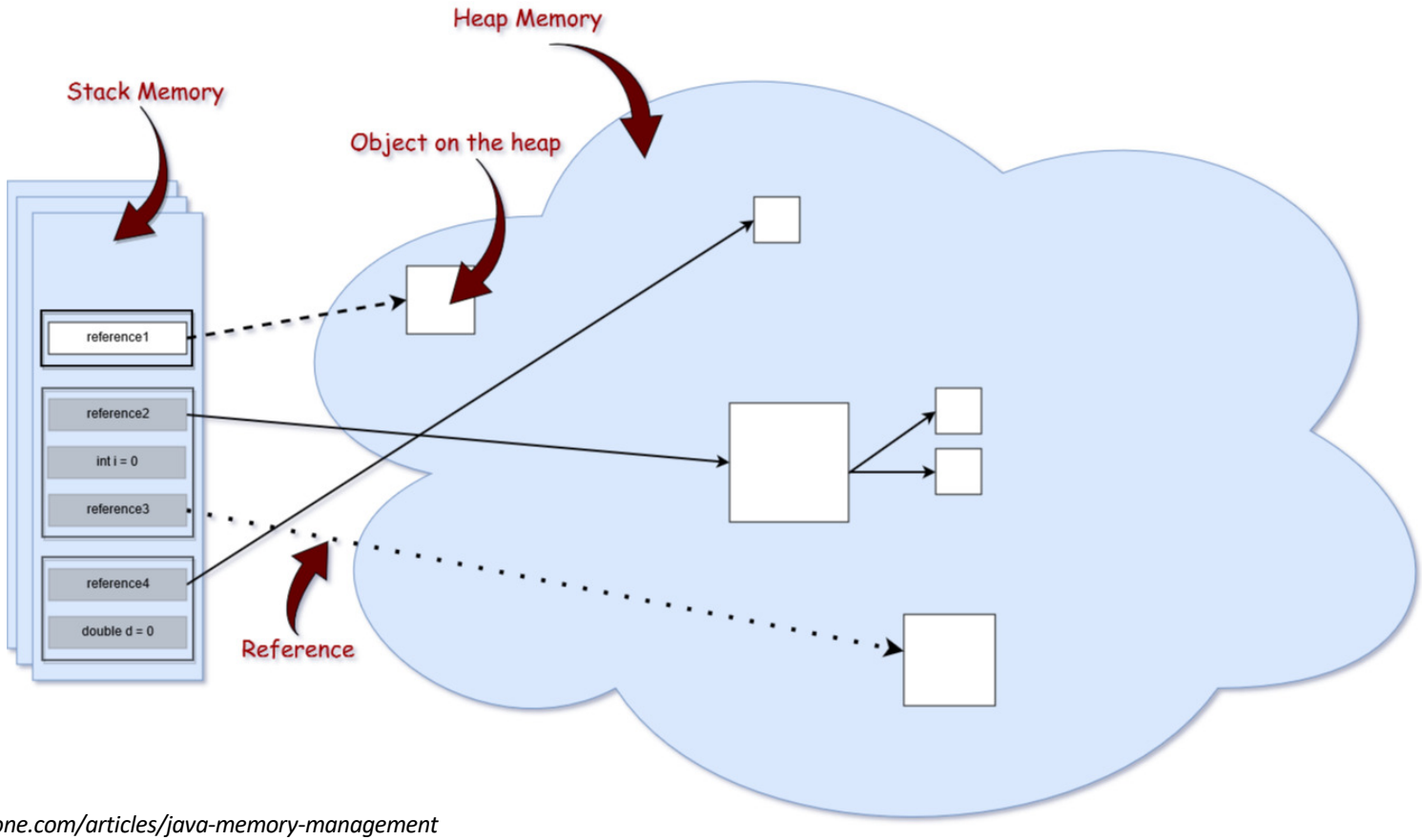


Image Source: https://dzone.com/articles/java-memory-management

Object Identity

```
private static CourseSchedule createSchedule() {
    DayOfWeek[] pDayOfWeek = new DayOfWeek[2];
    pDayOfWeek[0] =  DayOfWeek.WEDNESDAY;
    pDayOfWeek[1] =  DayOfWeek.FRIDAY;
    LocalTime startTime = LocalTime.of( hour: 14, minute: 35, second: 00);
    LocalTime endTime  = LocalTime.of( hour: 15, minute: 55, second: 00);

    CourseSchedule schedule =  new CourseSchedule(new Semester(Semester.Term.Fall,  pYear: 2020), pDayOfWeek,
            startTime, endTime);
    return schedule;
}
```

Variables

- pDayOfWeek = {DayOfWeek[2]@497}
- startTime = {LocalTime@498} "14:35"
- endTime = {LocalTime@499} "15:55"
- schedule = {CourseSchedule@506} "Schedule: Fall-2020, [WEDNESDAY, FRIDAY], from 14:35 to 15:55"
  - aSemester = {Semester@507} "Fall-2020"
  - aDayOfWeek = {DayOfWeek[2]@519}
  - aStartTime = {LocalTime@498} "14:35"
  - aEndTime = {LocalTime@499} "15:55"

Object Equality: True or False?

```
Card card1 = new Card(Card.Rank.FOUR, Card.Suit.CLUBS);
Card card2 = new Card(Card.Rank.FOUR, Card.Suit.CLUBS);
Card card3 = card1;

System.out.println(card1 == card2);
System.out.println(card1 == card3);
System.out.println(card1.equals(card2));
System.out.println(card1.equals(card3));
```

Object Equality

```
Card card1 = new Card(Card.Rank.FOUR, Card.Suit.CLUBS);
Card card2 = new Card(Card.Rank.FOUR, Card.Suit.CLUBS);
Card card3 = card1;

System.out.println(card1 == card2);
System.out.println(card1 == card3);
System.out.println(card1.equals(card2));
System.out.println(card1.equals(card3));
```

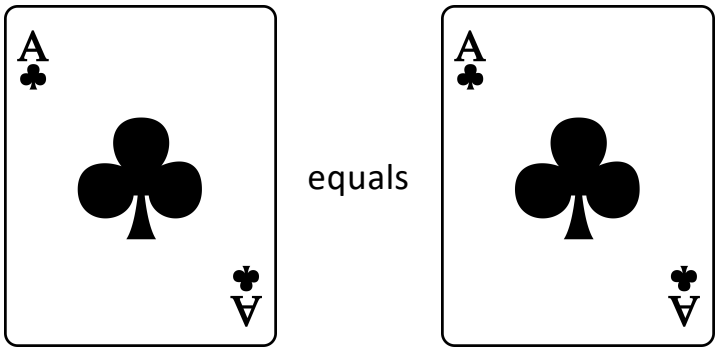
Reference equality

Variables refer to (point to) the same object in the memory

Reference Equality

- The most discriminating possible equivalence relation on objects

What about when logical equality is needed?



Logical equality: Using `Object.equals` method

```
public class Object {
   public boolean equals(Object o) {
      return this == o; // reference equality
   }
}
```

Implements an equivalence relation on non-null object references.

Reflexive: x.equals(x) == true

Symmetric: x.equals(y) ⇔ y.equals(x)

Transitive: x.equals(y) ∧ y.equals(z) ⇔ x.equals(z)

Consistent: x.equals(x) == x.equals(x)

For non-null reference value x x.equals(null) == false

Override `equals` method

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

   if (getClass() != obj.getClass())
      return false;

   Card other = (Card) obj;

   return aIsJoker == other.aIsJoker
      && aRank.equals(other.aRank)
      && aSuit.equals(other.aSuit)
}
```

True or False (after overriding `equals`)?

```
Card card1 = new Card(Card.Rank.FOUR, Card.Suit.CLUBS);
Card card2 = new Card(Card.Rank.FOUR, Card.Suit.CLUBS);
Card card3 = card1;

System.out.println(card1 == card2);
System.out.println(card1 == card3);
System.out.println(card1.equals(card2));
System.out.println(card1.equals(card3));
```

Also override `Object.hashCode` method

```
public int hashCode()
```

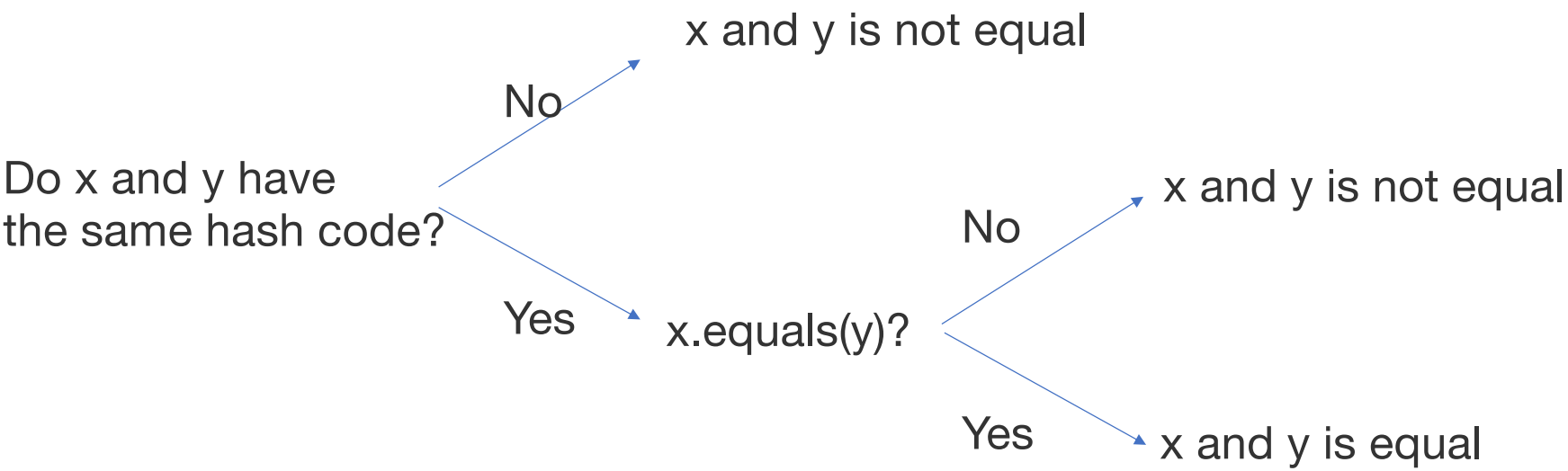
Returns a hash code value for the object. This method is supported for the benefit of hash tables such as those provided by HashMap.

Self-Consistent: o.hashCode() == o.hashCode()

Consistent with Equals:

x.equals(y) => x.hashCode() == y.hashCode()

Prefiltering for equality



Override hashCode() method

```
@Override
public int hashCode() {
    return 1;
}

@Override
public int hashCode() {
       return Boolean.hashCode(aIsJoker)
              + aRank.hashCode()
              + aSuit.hashCode();
}
```

Equality during Inheritance

```
public class CardWithDesign extends Card {
    public enum Design{ CLASSIC, ARTISTIC, FUN}

    Design aStyle;

    public CardWithDesign(Rank pRank, Suit pSuit, Design pStyle) {
        super(pRank, pSuit);
        this.aStyle = pStyle;
    }
    public CardWithDesign(Design pStyle) {
        super();
        this.aStyle = pStyle;
    }
}
```

```
Card card1 = new CardWithDesign(Card.Rank.FOUR, Card.Suit.CLUBS,
       CardWithDesign.Design.ARTISTIC);
Card card2 = new CardWithDesign(Card.Rank.FOUR, Card.Suit.CLUBS,
       CardWithDesign.Design.CLASSIC);

System.out.println(card1.equals(card2));
```

```
Card card3 = new Card(Card.Rank.FOUR, Card.Suit.CLUBS);
System.out.println(card1.equals(card3));
System.out.println(card3.equals(card1));
```

Violate Symmetric property

```
System.out.println(card2.equals(card3));
```

Violate Transitive property

Solution?

Make the comparison between supertype and subtype return false

Favor composition over inheritance (More during Module-Composition)