

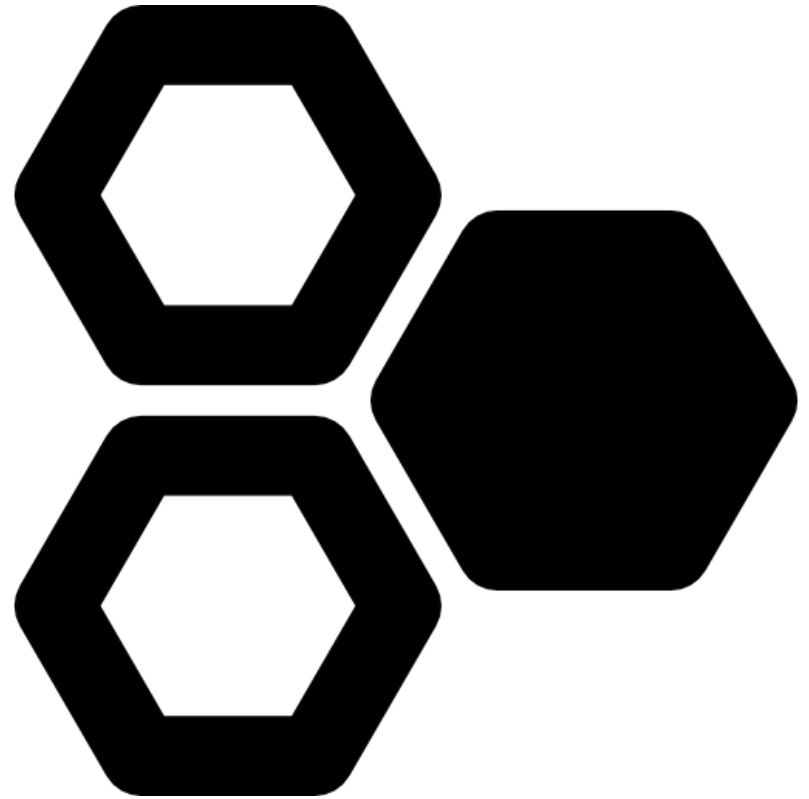
Relations between Classes

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Outline

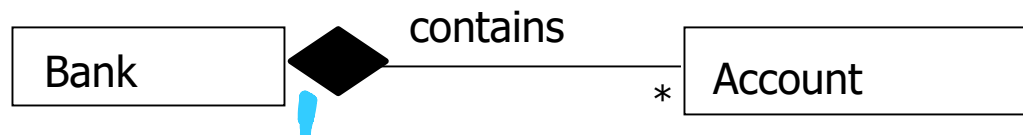
- Relations between Classes
- Introduction to Arrays and Lists
- Enumeration
- Exceptions

Relations between Classes



Relations between Classes

- Classes can be related to other classes in 4 ways:
 - Association
 - Aggregation (**has-a + whole-part** relationship)
 - Composition (**composed of + part cannot exist without the whole**)
 - Inheritance (**is-a relation**)
- Example:
 - An Account has an Owner (1 to 1)
 - A Bank has many Accounts (1 to many)
 - We say that Bank **aggregates** many Accounts



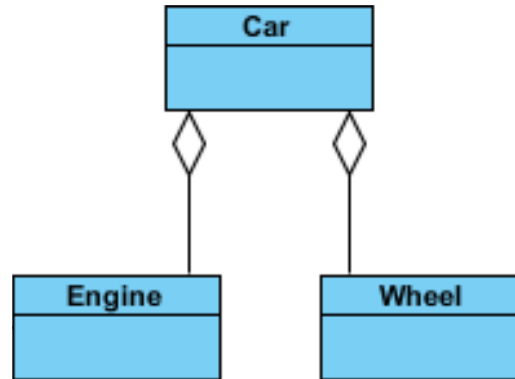
Association

- Association is a very generic relationship used to represent when one class uses the functionalities provided by another class

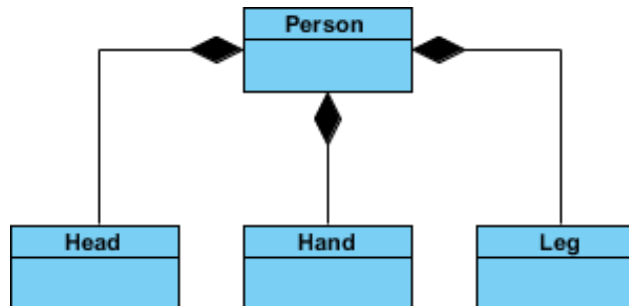


Aggregation vs. Composition

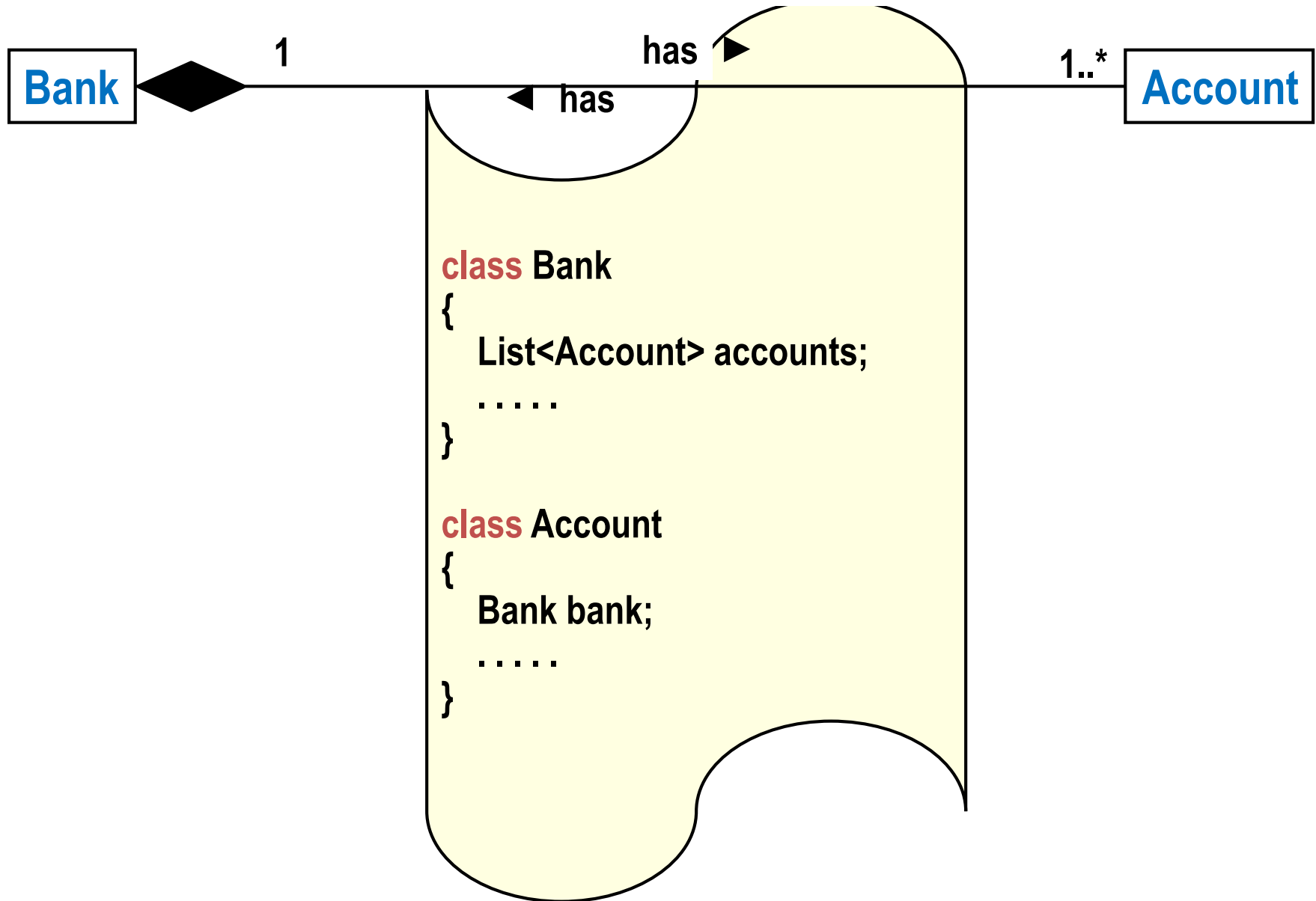
- **Aggregation** = Part can exist without the WHOLE



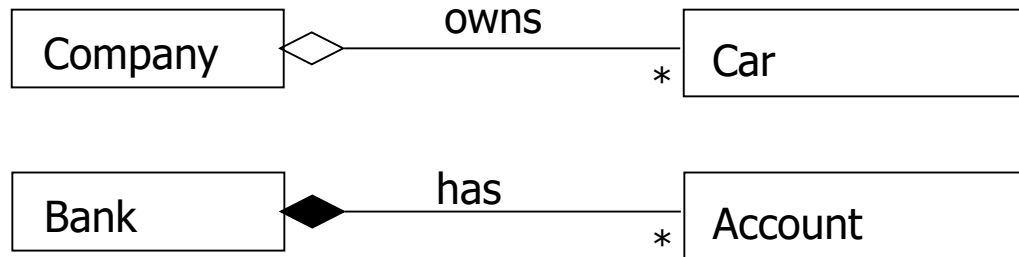
- **Composition** = OWNER class object owns another PART class object and that PART cannot meaningfully exist without the OWNER



Implementation of bidirectional association

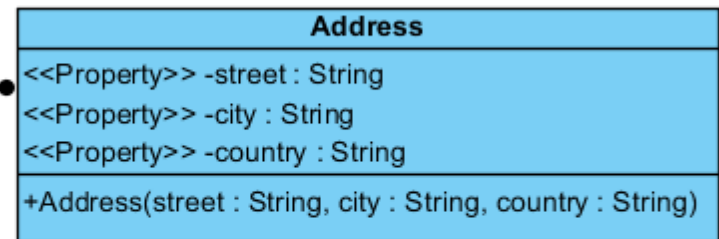
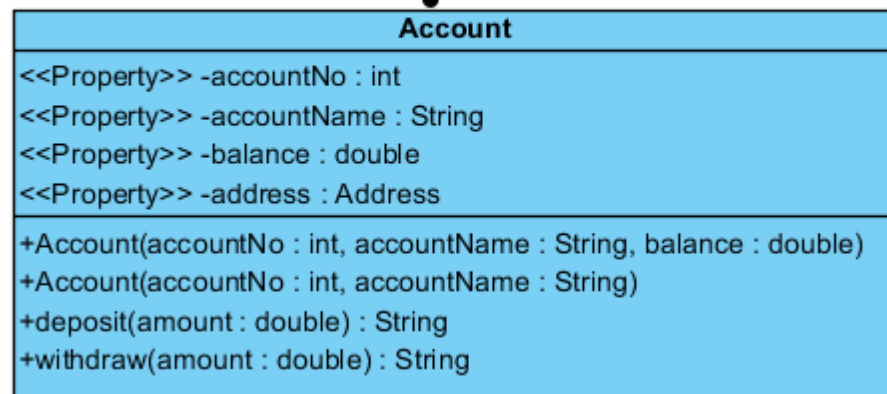
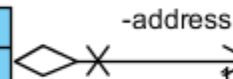
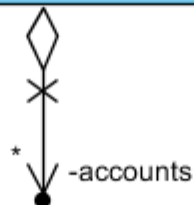
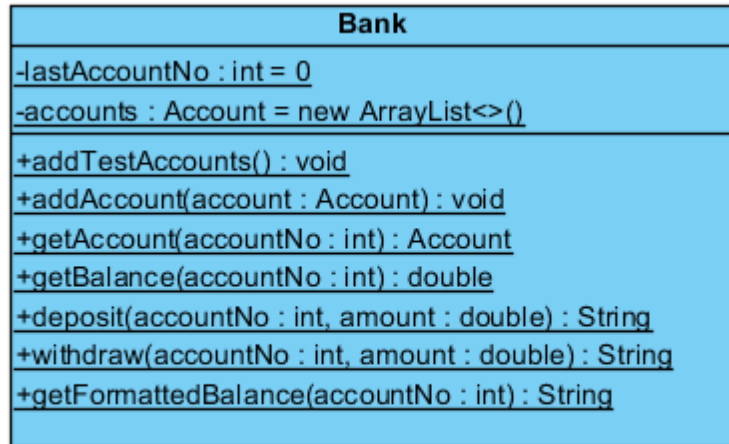


Aggregation



- Aggregation represents “whole-part” / “contains” relationship
 - Part instances can be added to and removed from the aggregate
- The 1 to many aggregation is represented in the Whole class using an **array** or an **ArrayList**

Composition Examples



Arrays and Lists



A simple variable stores a single value

MEMORY

```
int num1 = 10;
```

```
int num2 = 20;
```

```
int num3 = 30;
```

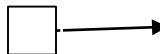
num1	10
num2	20
num3	30

An array object stores multiple values

```
int[] num = new int[3];
```

Declaration

num



MEMORY

num[0]	0
num[1]	0
num[2]	0

Allocation

Array objects can hold any type of object

```
int[] number = new int[100];           // stores 100 integers
```

```
double[] salesTax = new double[10];    // stores 10 doubles
```

```
char[] alphabet = new char[26];        // stores 26 characters
```

```
Student[] students = new Student[40];  // stores 40 students
```

The size of the array determines the number of elements in the array.

Array elements are initialized to the type's default value

```
int[] = new num[3];
```

num

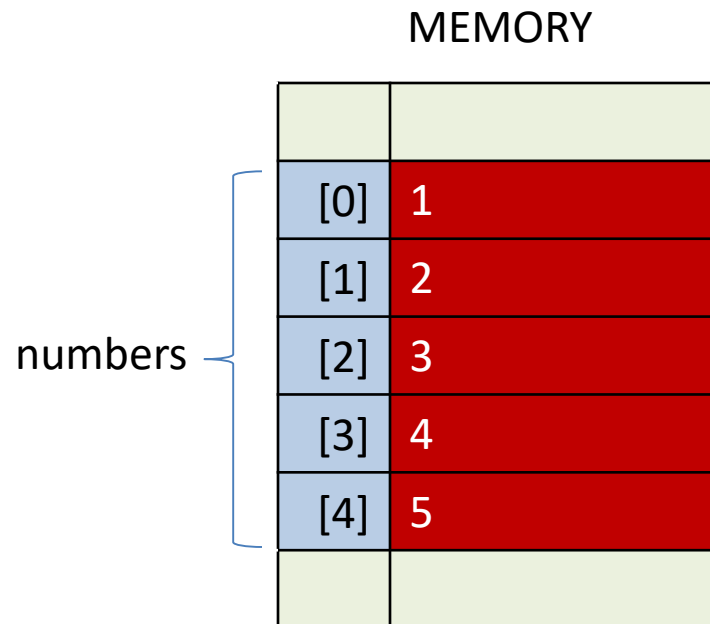


MEMORY

num[0]	0
num[1]	0
num[2]	0

You may initialize an array explicitly

```
int[] numbers = {1, 2, 3, 4, 5};
```



Array elements are indexed

```
int[] numbers = new int[5];
```

MEMORY

	[0]	1
	[1]	2
numbers {	[2]	0
	[3]	0
	[4]	0

numbers[0] = 1;

numbers[1] = 2;

Arrays can be instance variables

```
public class Department {  
    private Employee[] employee;  
    ...  
}
```

Arrays can be local variables

```
public void getHourlyEmployees() {  
    Employee[] hourlyEmployee;  
    ...  
}
```

Arrays can be parameters

```
public static void main(String[] args) {  
    ...  
}
```

Arrays can be return values

```
public Employee[] getEmployees() {  
    ...  
}
```

Example - Method that returns an array

```
public int[] initArray(int size, int initValue) {  
    int[] array = new int[size];  
  
    for (int i = 0; i < array.length; i++) {  
        array[i] = initValue;  
    }  
  
    return array;  
}
```

Arrays are objects, thus

```
int[] a = {1, 2, 3};  
int[] b;
```

```
b = a;           // makes b and a refer to the same  
                  // memory location
```

Example method that copies an array

```
public void copyArray(int[] source, int[] target) {  
    // Both arrays must be the same size.  
    target = new int[source.length];  
    for (int i = 0; i < source.length; i++) {  
        target[i] = source[i];  
    }  
}
```

Arrays are objects, thus

```
int[] a = {1, 2, 3};  
int[] b = {1, 2, 3};
```

```
if (a == b) {...}           // evaluates to false  
                             // since a and b refer to two  
                             // different memory locations
```

Example - Method that tests for array equality

```
public boolean areEqual(int[] array1, int[] array2) {  
    if (array1.length != array2.length) {  
        return false;  
    } else {  
        for(int i = 0; i < array1.length; i++) {  
            if(array1[i] != array2[i])  
                return false;  
        }// end for  
    }// end if  
    return true;  
}
```

Use linear(sequential) search to locate values

MEMORY

[0]	12
[1]	1
[2]	44
[3]	15
[4]	6

an array {

Q: is this the value? A: No

Q: is this the value? A: No

Q: is this the value? A: No

Q: is this the value? A: Yes

Q: is this the value 15 in the array?

Linear Search

```
// Returns true if array contains item, false otherwise.
private boolean contains(String[] items, String item) {
    for(int i = 0; i < items.length; i++) {
        if (items[i].equalsIgnoreCase(item)) {
            return true;
        }
    } // end for
    return false;
}
```


Lists

- Problem
 - You must know the array size when you create the array
 - Although Java arrays are better than C++ arrays since the size does not need to be a compile-time constant
 - Array size cannot change once created.
- Solution:
 - Use **ArrayList**: they stretch as you add elements to them

ArrayList methods

- Create empty list
`new ArrayList<>()`
- Add entry to end
`add(value)` (adds to end)
- Retrieve n^{th} element
`get(index)`
- Check if element exists in list
`contains(element)`
- Remove element
`remove(index)` or `remove(element)`
- Find the number of elements
`size()`

ArrayList Example

```
import java.util.*; // Don't forget this import
```

```
public class ListTest2 {
```

```
    public static void main(String[] args) {
```

```
        List<String> entries = new ArrayList<>();
```

```
        double d;
```

```
        while((d = Math.random()) > 0.1) {
```

```
            entries.add("Value: " + d);
```

```
        }
```

```
        for(String entry: entries) {
```


```
            System.out.println(entry);
```

```
        }
```

```
    }
```

```
}
```

This tells Java your list will contain only strings.





Enumeration

```
enum LightState {...}
```

Enumerations

- The basic `enum` type defines a set of constants represented as unique identifiers
- An `enum` type is declared with an `enum declaration`, which is a comma-separated list of `enum` constants
- The declaration may optionally include other components of traditional classes, such as constructors, fields and methods

Enumerations (Cont.)

- Each **enum** declaration declares an **enum** class with the following restrictions:
 - **enum** constants are implicitly **final**, because they declare constants that shouldn't be modified.
 - **enum** constants are implicitly **static**.
 - Any attempt to create an object of an enum type with operator **new** results in a compilation error.
 - **enum** constants can be used anywhere constants can be used, such as in the **case** labels of **switch** statements and the condition of an if statement.
- For every **enum**, the compiler generates the **static** method **values** that returns an array of the **enum**'s constants.
- When an **enum** constant is converted to a **String**, the constant's identifier is used as the **String** representation.

enum is actually a class

```
enum LightState {
```

LightState class

```
    OFF,  
    ON,  
    DIMMED,  
    FLICKERING
```

public static
objects

```
}
```

<EnumDemo.java>

```
public class EnumDemo {
    enum LightState {
        // Each object is initialized to a color.
        OFF("black"),
        ON("white"),
        DIMMED("gray"),
        FLICKERING("red");

        private final String colorField;

        // Private constructor to set the color.
        private LightState(String color) {
            colorField = color;
        }

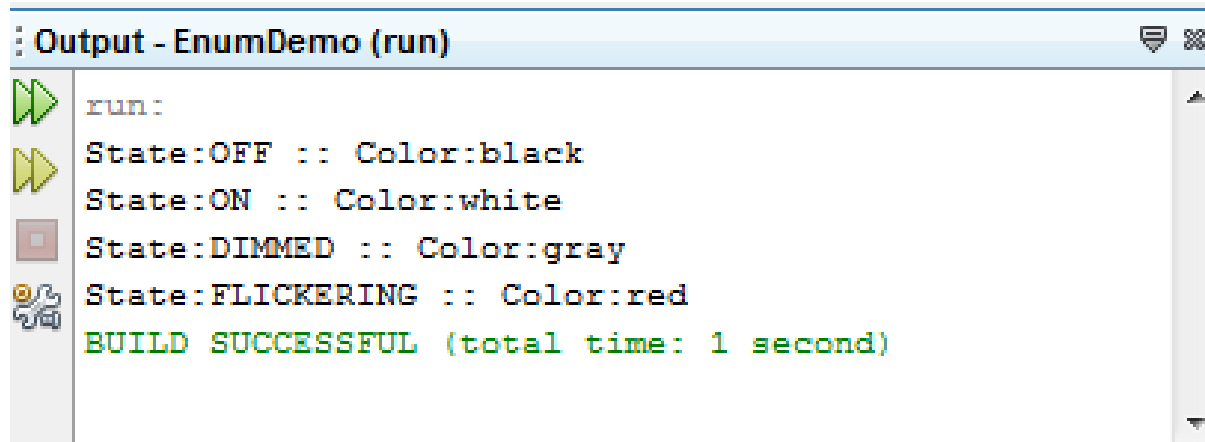
        // Public accessor to get color.
        public String getColor() {
            return colorField;
        }
    }

    public static void main(String[] args) {
        LightState off = LightState.OFF;
        LightState on = LightState.ON;
        LightState dimmed = LightState.DIMMED;
        LightState flickering = LightState.FLICKERING;
    }
}
```

You can enhance the enum class with instance variables and methods

<EnumDemo.java>

```
System.out.println("State:" + off.toString() +  
                    " :: Color:" + off.getColor());  
System.out.println("State:" + on.toString() +  
                    " :: Color:" + on.getColor());  
System.out.println("State:" + dimmed.toString() +  
                    " :: Color:" + dimmed.getColor());  
System.out.println("State:" + flickering.toString() +  
                    " :: Color:" + flickering.getColor());  
    }// end main()  
}// end EnumDemo
```



The screenshot shows an IDE's Output window titled "Output - EnumDemo (run)". The window contains the following text:

```
run:  
State:OFF :: Color:black  
State:ON :: Color:white  
State:DIMMED :: Color:gray  
State:FLICKERING :: Color:red  
BUILD SUCCESSFUL (total time: 1 second)
```

On the left side of the window, there are four icons: a green play button, a yellow play button, a red stop button, and a blue and white icon representing a class or package structure.



Exceptions

Error.

Throwing Exceptions

```
1 // Time1.java
2 // Time1 class declaration maintains the time in 24-hour format.
3
4 public class Time1 {
5     private int hour; // 0 - 23
6     private int minute; // 0 - 59
7     private int second; // 0 - 59
8
9     // set a new time value using universal time; throw an
10    // exception if the hour, minute or second is invalid
11    public void setTime(int hour, int minute, int second) {
12        // validate hour, minute and second
13        if (hour < 0 || hour >= 24 || minute < 0 || minute >= 60 ||
14            second < 0 || second >= 60) {
15            throw new IllegalArgumentException(
16                "hour, minute and/or second was out of range");
17        }
18
19        this.hour = hour;
20        this.minute = minute;
21        this.second = second;
22    }
```

Throwing Exceptions

- Method `setTime` declares three `int` parameters and uses them to set the time.
- Lines 13–14 test each argument to determine whether the value is outside the proper range.
- For incorrect values, `setTime` throws an exception of type `IllegalArgumentException`
 - Notifies the client code that an invalid argument was passed to the method.
 - The `throw statement` creates a new object of type `IllegalArgumentException` and specifies a custom error message.
 - `throw` statement immediately terminates method `setTime` and the exception is returned to the calling method that attempted to set the time.

try and catch

```
18 // attempt to set time with invalid values
19 try {
20     time.setTime(99, 99, 99); // all values out of range
21 }
22 catch (IllegalArgumentException e) {
23     System.out.printf("Exception: %s%n%n", e.getMessage());
24 }
25
26 // display time after attempt to set invalid values
27 displayTime("After calling setTime with invalid values", time);
28 }
29
30 // displays a Time1 object in 24-hour and 12-hour formats
31 private static void displayTime(String header, Time1 t) {
32     System.out.printf("%s%nUniversal time: %s%nStandard time: %s%n",
33         header, t.toUniversalString(), t.toString());
34 }
35 }
```

Lines 19 to 24 use **try...catch** to catch and handle the exception (e.g., display the error message to the user)

Banking System Example

QuBank 🔍

BankUI
<u>+main(args : String []) : void</u>

**This is the main
class to run the App**

Account
<<Property>> -accountNo : int
<<Property>> -accountName : String
<<Property>> -balance : double
+Account(accountNo : int, accountName : String, balance : double)
+Account(accountNo : int, accountName : String)
+deposit(amount : double) : String
+withdraw(amount : double) : String

Bank has
many
Accounts

Bank
<u>-lastAccountNo : int = 0</u>
<u>-accounts : Account = new ArrayList<>()</u>
<u>+addTestAccounts() : void</u>
<u>+addAccount(account : Account) : void</u>
<u>+getAccount(accountNo : int) : Account</u>
<u>+getBalance(accountNo : int) : double</u>
<u>+deposit(accountNo : int, amount : double) : String</u>
<u>+withdraw(accountNo : int, amount : double) : String</u>
<u>+getFormattedBalance(accountNo : int) : String</u>



Bookstore System example

QuBookstore 🔍

BookStoreUI
<pre>+main(args : String []) : void +addItemsToShoppingCart() : ShoppingCart +displayShoppingCart(shoppingCart : ShoppingCart) : void</pre>

This is the main class to run the App

DataEntryUtils
<pre>+getString(scanner : Scanner, prompt : String) : String +getInt(scanner : Scanner, prompt : String) : int +getInt(scanner : Scanner, prompt : String, min : int, max : int) : int +getDouble(scanner : Scanner, prompt : String) : double +getDouble(scanner : Scanner, prompt : String, min : double, max : double) : double</pre>

This is a utility class to ease data entry

A CartItem is for one particular book

CartItem
<pre><<Property>> -quantity : int <<Property>> -book : Book +CartItem() +CartItem(book : Book, quantity : int) +getTotal() : double +getFormattedTotal() : String</pre>

ShoppingCart
<pre><<Property>> -cartItems : CartItem +ShoppingCart() +addItem(cartItem : CartItem) : void +getTotal() : double +getFormattedTotal() : String</pre>

A Shopping Cart contains 1 or many items

Book
<pre><<Property>> -code : String <<Property>> -description : String <<Property>> -price : double +Book() +Book(code : String, description : String, price : double) +getFormattedPrice() : String</pre>

BookCatalog
<pre>-books : Book = new ArrayList<>() +addTestBooks() : void +getBook(bookCode : String) : Book</pre>

The BookCatlog contains many books