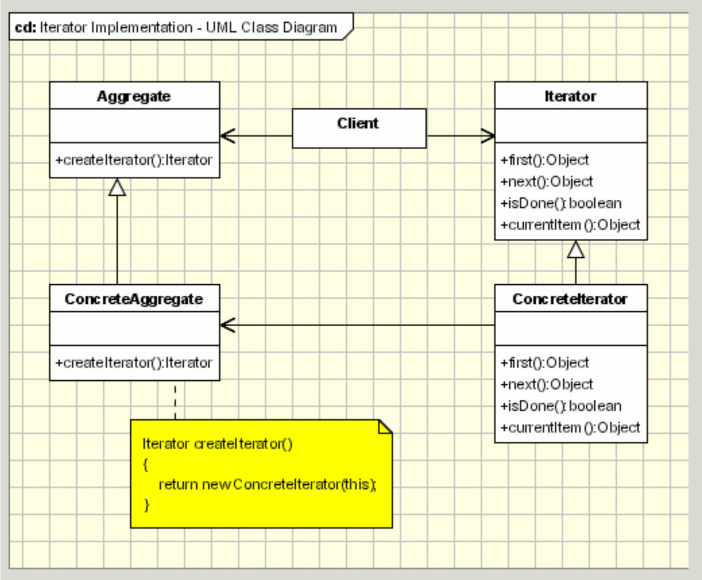
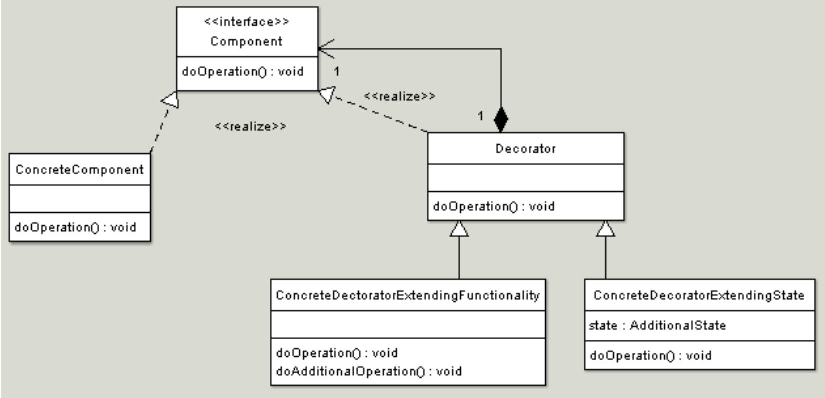
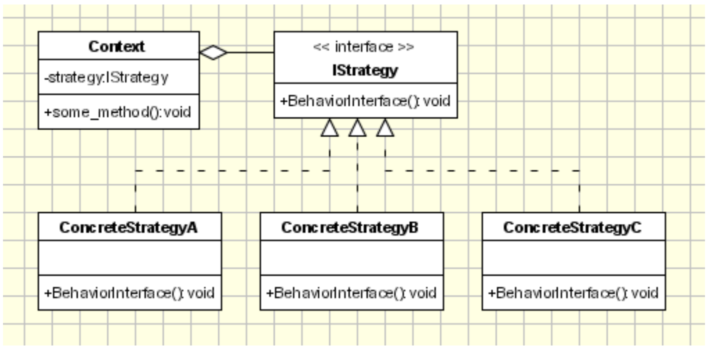
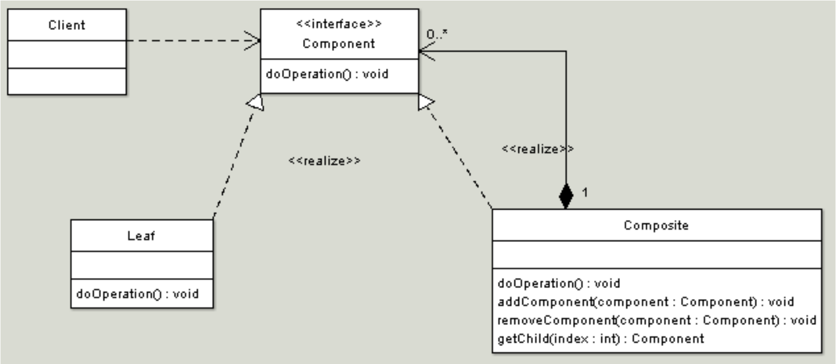
DESIGN PATTERNS

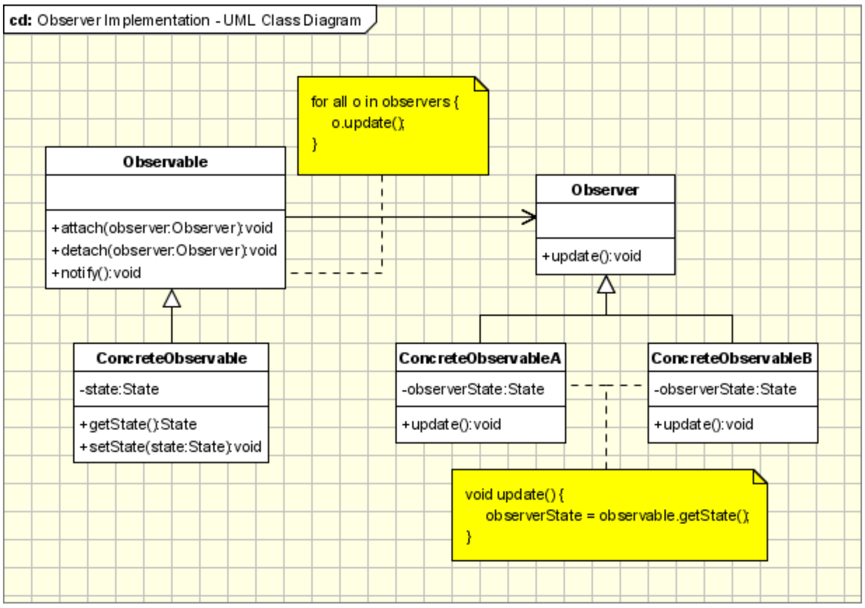


```
Iterator createIterator()
{
    return new ConcreteIterator(this);
}
```









LABS

OBJECT-ORIENTED PROGRAMMING

CREATE AN **EMPLOYEE** CLASS WHICH HAS PRIVATE FIELDS FOR AN EMPLOYEE'S NAME AND SALARY

```
public class Employee implements Cloneable {
         private String name;
         private int salary;

         /**
          * Creates a new Employee given a name and salary.
          * @param startEmployeeName
          * @param startSalary
          */
         public Employee (String startEmployeeName, int startSalary) {
                  this.name = startEmployeeName;
                  this.salary = startSalary;
         }
}
```

CREATE A **MANAGER** CLASS THAT IS A SUBTYPE OF **EMPLOYEE**, WHICH ALSO HAS A PRIVATE FIELD FOR A MANAGER'S HIRE DATE

```
public class Manager extends Employee {
         private Calendar hireDate;

         /**
         * Creates a new Manager given a name, salary and hire date.
         * @param startEmployeeName
         * @param startSalary
         * @param hireDate
         */
        public Manager (String startEmployeeName, int startSalary, Calendar hireDate) {
                super (startEmployeeName, startSalary);
                this.hireDate = hireDate;
        }
}
```

DEFINE CONSTRUCTORS FOR THE CLASSES, AND PUBLIC GETTER AND SETTER METHODS FOR THE FIELDS: DOCUMENT THEM USING JAVADOC

```
        /**
         * Sets the salary of the employee.
         * @param salary The salary of the employee.
         */
        public void setSalary (int salary) {
                this.salary = salary;
        }
        /**
         * Returns the salary of the Employee.
         * @return the salary of the Employee.
         */
        public int getSalary () {
                return salary;
        }
```

DEFINE THE STANDARD METHODS TOSTRING, EQUALS AND CLONE FOR **EMPLOYEE** AND **MANAGER**

- Employee should implement the Cloneable interface
- When you implement equals, you need to implement hashCode

```
public class Employee implements Cloneable {
        ...
        public String toString () {
                return getClass().getName() + this.name + "(" + this.salary + ")";
        }

        @Override
        public Object clone () {
                try {
                        return super.clone();
                } catch (CloneNotSupportedException exc) {
                        exc.printStackTrace();
                        return null;
                }
        }

        @Override
        public boolean equals (Object obj) {
                if (obj == null){
                        return false;
                }
                if (getClass() != obj.getClass()) {
                        return false;
                }
                Employee other = (Employee) obj;
                return this.name == other.name && this.salary == other.salary;
        }

        @Override
        public int hashCode() {
                int hash = 0;
                hash += 7 * name.hashCode();
                hash += 13 * salary;
                return hash;
        }
}
```

- The methods for **Manager** should call those for **Employee** using the **super** construct

```
public class Manager extends Employee {
        ...
        @Override
        public String toString () {
                return super.toString() + this.getHireDateString();
        }

        @Override
        public Manager clone () {
                Manager clone = (Manager) super.clone();
                clone.setHireDate(this.getHireDate());
                return clone;
        }

        @Override
        public boolean equals (Object obj) {
                if (obj == null) {
                        return false;
                }
                if (getClass() != obj.getClass()) {
                        return false;
                }
                Manager other = (Manager) obj;
                return this.hireDate == other.hireDate && super.equals(other);
        }

        @Override
        public int hashCode() {
                int hash = super.hashCode();
                hash += 11 * hireDate.hashCode();
                return hash;
        }
}
```

- What output do you expect when `getClass().getName()` is called in the `toString` method of **Employee** with a **Manager** object?
  - This should return **Manager**.

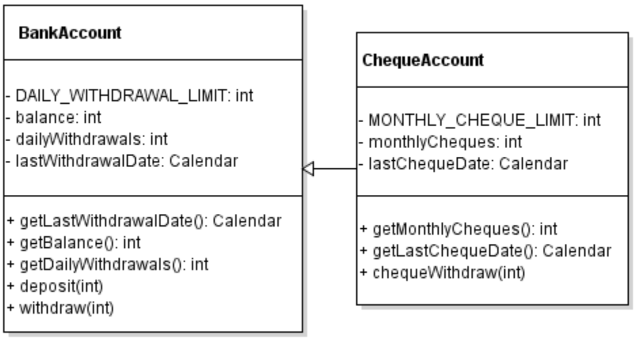
CREATE A CLASS FOR TESTING THE **EMPLOYEE** AND **MANAGER** CLASSES AND DEFINE SOME TESTS FOR YOUR METHODS

- What do you expect when you test whether an **Employee** is equal to a clone of the **Employee**?
  - They should be equal since their classes and fields are the same.
- What do you expect when you test whether a **Manager** is equal to an **Employee** with the same name and salary (and vice versa)?
  - They should not be equal since their classes differ.
- What do you expect when you test whether the name of an **Employee** is equal to the name of a clone of the **Employee**?
  - They should be equal.
- If you change the hire date of a clone of a **Manager**, is the hire date of the original **Manager** also changed?
  - No, because we use the `Cloneable` interface to make a deep copy in the clone function.

PROGRAMMING BY CONTRACT

DRAW A UML CLASS DIAGRAM THAT INCORPORATES THE FOLLOWING REQUIREMENTS

- A **BankAccount** class for maintaining a customer's bank balance
  - Each bank account should have a current balance and methods implementing deposits and withdrawals
  - Money can only be withdrawn from an account if there are sufficient funds
  - Each account has a withdrawal limit of $800 per day
- A subclass of **BankAccount** called **ChequeAccount**
  - In addition to the constraints on **BankAccount**, there is a limit of 5 cheque withdrawals per month


BankAccount
- DAILY_WITHDRAWAL_LIMIT: int
- balance: int
- dailyWithdrawals: int
- lastWithdrawalDate: Calendar
+ getLastWithdrawalDate(): Calendar
+ getBalance(): int
+ getDailyWithdrawals(): int
+ deposit(int)
+ withdraw(int)
ChequeAccount
- MONTHLY_CHEQUE_LIMIT: int
- monthlyCheques: int
- lastChequeDate: Calendar
+ getMonthlyCheques(): int
+ getLastChequeDate(): Calendar
+ chequeWithdraw(int)

GIVE JAVA IMPLEMENTATIONS OF BOTH CLASSES

```java
import java.util.Calendar;

public class BankAccount {

        private static final int DAILY_WITHDRAWAL_LIMIT = 800;
        private int balance;
        private int dailyWithdrawals;
        private Calendar lastWithdrawalDate;

        /**
         * Creates a new BankAccount given a balance.
         * @param balance
         * @return BankAccount
         */
        public BankAccount (int balance) {
                super();
                this.balance = balance;
                this.dailyWithdrawals = 0;
                Calendar now = Calendar.getInstance();
                this.lastWithdrawalDate = now;
        }

        /**
         * Gets the date of the last withdrawal from the BankAccount.
         * @return last withdrawal date of the BankAccount as a Calendar
         */
        public Calendar getLastWithdrawalDate () {
                return lastWithdrawalDate;
        }

        /**
         * Gets the current balance of the BankAccount.
         * @return current balance as an integer
         */
        public int getBalance () {
                return balance;
        }

        /**
         * Gets the total withdrawals from the BankAccount today.
         * @return total withdrawals as an integer
         */
        public int getDailyWithdrawals () {
                return dailyWithdrawals;
        }

        /**
         * Deposits money into the BankAccount.
         * @precondition depositValue is positive.
         * @postcondition balance increases.
         * This post-condition must be satisfied because the only operation in this
method is addition.
         * @param depositValue The value to deposit in the BankAccount
         */
        public void deposit (int depositValue) throws Exception {
                if (depositValue < 0) {
                        throw new Exception("Deposit cancelled: Value to deposit must
be positive.");
                }
                this.balance = this.balance + depositValue;
        }

        /**
         * Withdraws money from the BankAccount.
         * @precondition withdrawalValue is positive, balance is positive,
DAILY_WITHDRAWAL_LIMIT not reached.
         * @postcondition balance decreases.
         * @param withdrawalValue Amount to withdraw from the BankAccount
         * @throws Exception due to either insufficient funds or exceeding daily
withdrawal limit
         */
        public void withdraw (int withdrawalValue) throws Exception {
                /*
                 * How are limits enforced?
                 * Last withdrawal date is used to determine when dailyWithdrawals is
reset.
                 * There are checks for whether there are sufficient funds to withdraw,
whether the value to withdraw is positive and
                 * whether the daily limit has been exceeded. These will throw
exceptions.
                 */
                // Check when last withdrawal occurred. If on a previous day, reset
dailyWithdrawals to 0.
                Calendar today = Calendar.getInstance();
                if ((getLastWithdrawalDate().get(Calendar.DATE)) <
today.get(Calendar.DATE) ||
                                (getLastWithdrawalDate().get(Calendar.MONTH)) <
today.get(Calendar.MONTH) ||
                                (getLastWithdrawalDate().get(Calendar.YEAR)) <
today.get(Calendar.YEAR)) {
                        this.dailyWithdrawals = 0;
                }

                // Check withdrawalValue is positive.
                if (withdrawalValue < 0) {
                        throw new Exception("Withdrawal cancelled: Value to withdraw
must be positive");
                // Check balance has sufficient funds for withdrawal.
                } if ((balance - withdrawalValue) < 0) {
                        throw new Exception("Withdrawal cancelled: Insufficient
funds");
                // Check that daily withdrawal limit is not exceeded.
                } else if ((withdrawalValue + this.dailyWithdrawals) >
DAILY_WITHDRAWAL_LIMIT) {
                        throw new Exception("Withdrawal cancelled: exceeded daily
withdrawal limit ($" + DAILY_WITHDRAWAL_LIMIT +")");
                } else {
                        this.balance = this.balance - withdrawalValue;
                        this.lastWithdrawalDate = today;
                        dailyWithdrawals += withdrawalValue;
                }
        }
}

import java.util.Calendar;

public class ChequeAccount extends BankAccount {
        private static final int MONTHLY_CHEQUE_LIMIT = 5;
        private int monthlyCheques;
        private Calendar lastChequeDate;

        /**
         * Creates a new ChequeAccount given a balance and monthly cheques used.
         * @param balance balance of the ChequeAccount
         * @param monthlyCheques number of cheques used so far this month
         */
        public ChequeAccount (int balance, int monthlyCheques) {
                super(balance);
                this.monthlyCheques = monthlyCheques;
                Calendar now = Calendar.getInstance();
                this.lastChequeDate = now;
        }

        /**
         * Returns the date when the last cheque was issued.
         * @return date when the last cheque was issued as a Calendar
         */
        public Calendar getLastChequeDate () {
                return lastChequeDate;
        }

        /**
         * Returns the number of cheques used this month.
         * @return the number of cheques used this month
         */
        public int getMonthlyCheques () {
                return monthlyCheques;
        }

        /**
         * Uses a cheque to withdraw from ChequeAccount.
         * @precondition withdrawalValue is positive, MONTHLY_CHEQUE_LIMIT not reached,
balance has sufficient funds.
         * @postcondition balance decreases.
         * @param withdrawalValue value to withdraw using a cheque
         * @throws Exception if insufficient funds or exceeded daily withdrawal limit or
if exceeded monthly cheque limit
         */
        public void chequeWithdraw (int withdrawalValue) throws Exception {
                // Reset monthlyCheques if previous cheque was issued last month.
                Calendar today = Calendar.getInstance();
                if ((getLastChequeDate().get(Calendar.MONTH)) <
today.get(Calendar.MONTH) ||
                                (getLastChequeDate().get(Calendar.YEAR)) <
today.get(Calendar.YEAR)) {
                        this.monthlyCheques = 0;
                }

                // Check if withdrawalValue is positive.
                if (withdrawalValue < 0) {
                        throw new Exception("Withdrawal cancelled: Value to withdraw
must be positive");
                // Check if MONTHLY_CHEQUE_LIMIT has been reached.
                } else if ((1 + this.monthlyCheques) > MONTHLY_CHEQUE_LIMIT) {
                        throw new Exception("Withdrawal cancelled: exceeded monthly
cheque limit (" + MONTHLY_CHEQUE_LIMIT + ")");
                } else {
                        withdraw(withdrawalValue);
```

```
            this.lastChequeDate = today;
            monthlyCheques += 1;
        }
    }
}
```

- Explain how the limits on withdrawals are enforced within your system
    - Enforced using exceptions which are handled by the input system.

DEFINE A JUNIT TEST CASE TO TEST YOUR IMPLEMENTATIONS

```
import static org.junit.Assert.*;
import org.junit.*;
import banking.BankAccount;

public class BankAccount_withdrawal {

    @Test
    public void withdraw_normal_balancedecrease() {
        BankAccount testBankAccount = new BankAccount(100);
        try {
            testBankAccount.withdraw(100);
        } catch (Exception e) {
            fail();
        }
        assertEquals(0, testBankAccount.getBalance());
    }

    @Test
    public void withdraw_nofunds_exception() {
        BankAccount testBankAccount = new BankAccount(0);
        try {
            testBankAccount.withdraw(100);
        } catch (Exception e) {
            // Success!
        }
        assertEquals(0, testBankAccount.getBalance());
    }

    @Test
    public void withdraw_insufficientfunds_exception() {
        BankAccount testBankAccount = new BankAccount(50);
        try {
            testBankAccount.withdraw(100);
        } catch (Exception e) {
            // Success!
        }
        assertEquals(50, testBankAccount.getBalance());
    }

    @Test
    public void withdraw_negativeval_exception() {
        BankAccount testBankAccount = new BankAccount(600);
        try {
            testBankAccount.withdraw(-100);
        } catch (Exception e) {
            // Success!
        }
        assertEquals(600, testBankAccount.getBalance());
    }

    @Test
    public void withdraw_exceeddailylimit_exception() {
        BankAccount testBankAccount = new BankAccount(1000);
        try {
            testBankAccount.withdraw(900);
        } catch (Exception e) {
            // Success!
        }
```

```
                assertEquals(1000, testBankAccount.getBalance());
        }
}
```

OBJECT-ORIENTED DESIGN

- Consider a university enrolments system with the following requirements
    - Students enrol in courses that are offered in particular semesters
    - Students receive grades (pass, fail, etc.) for courses in particular semesters
    - Courses may have prerequisites (other courses) and must have credit point values
    - For a student to enrol in a course, s/he must have passed all prerequisite courses
    - Course offerings are broken down into multiple sessions (lectures, tutorials and labs)
    - Sessions in a course offering for a particular semester have an allocated room and timeslot
    - If a student enrols in a course, s/he must also enrol in some sessions of that course

DESIGN AN OBJECT-ORIENTED SYSTEM TO IMPLEMENT THE ABOVE REQUIREMENTS

- Define one or more use cases, e.g. for a student enrolling in a course that has a prerequisite that s/he has passed: Student enrolling in course with prerequisites passed
    - Student chooses classes
    - Class checks that prerequisites are passed
    - Student chooses sessions
    - Session checks that no clashes occur
    - Student enrols
- Provide CRC cards for your main classes

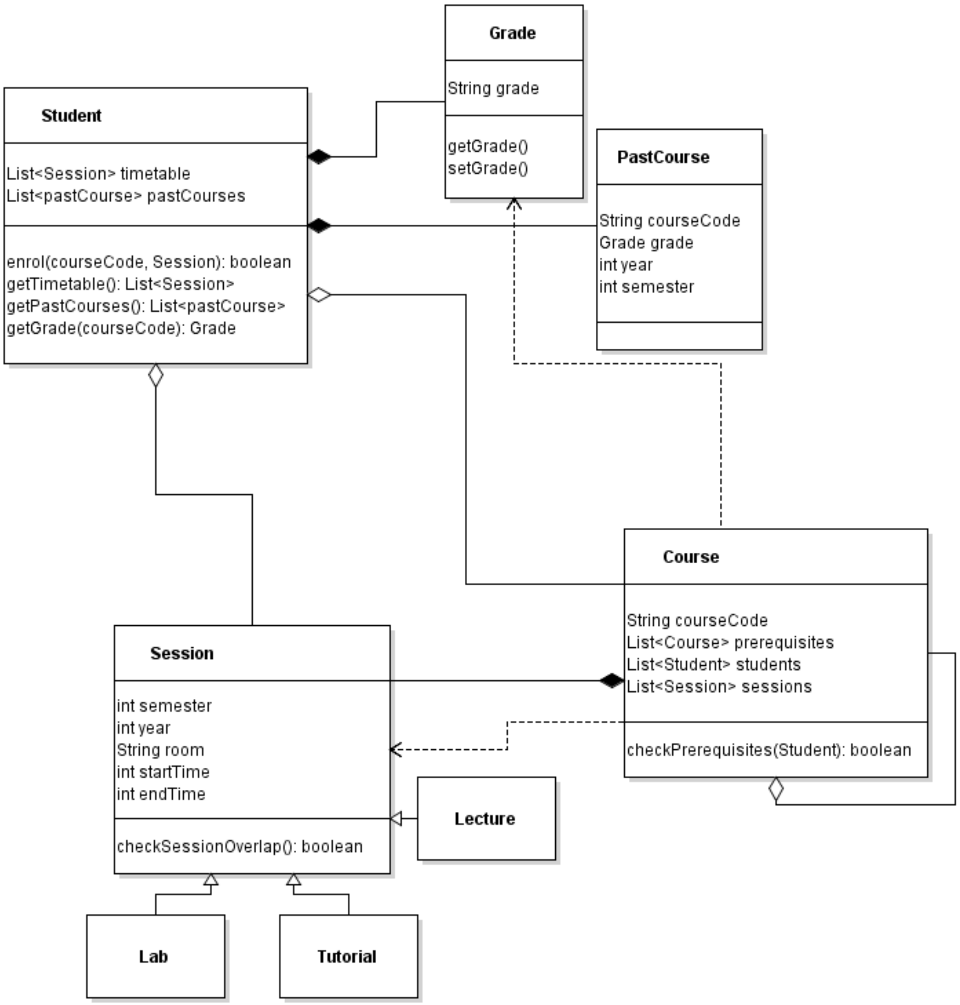
Class	**Student**
Responsibilities	Stores timetable for current semester Stores past courses and metadata Enrols
Collaborators	Grade, Course, Session

Class	**Grade**
Responsibilities	Represent the grade a student receives for a course
Collaborators	Student, Course

Class	**Course**
Responsibilities	Stores course code, prerequisites, students and sessions Checks if student satisfies prerequisites
Collaborators	Grade, Session, Student

Class	**Session**
Responsibilities	Stores session details for a course, for example, semester, room and class time Ensures that student doesn't have timetable clashes
Collaborators	Course, Student, session types (Lab, Lecture, Tutorial)

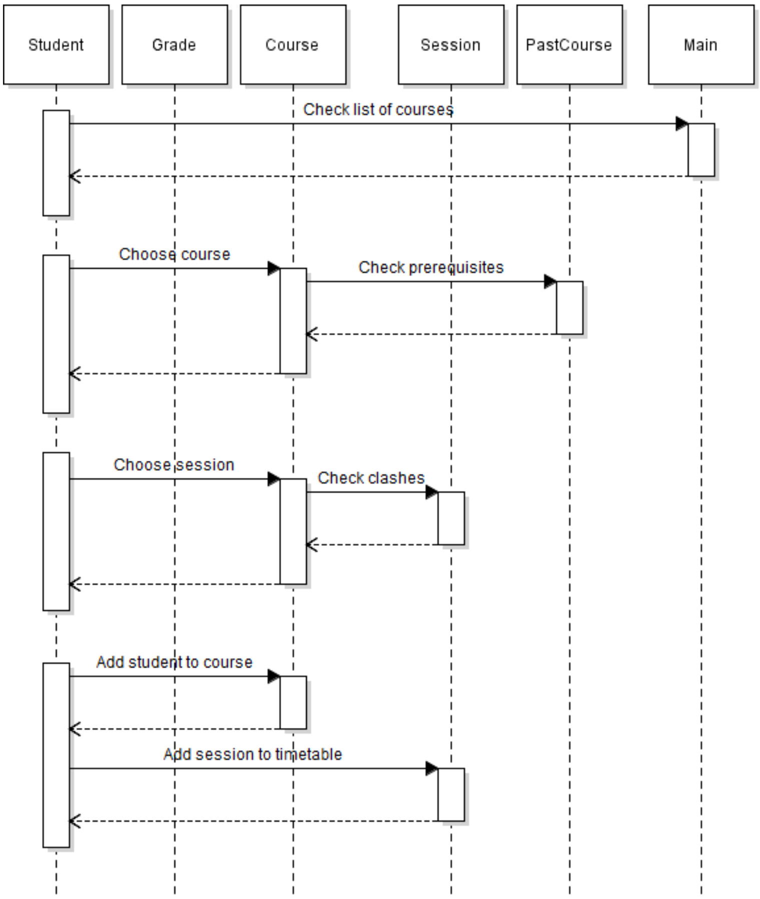
- Draw a UML class diagram for your initial design



- Clearly explain how your design distinguishes between a course and an instance of a course in a particular semester
    - Course represented by Course class, whereas instance of course is represented by the Session class.
- Identify any assumptions and design trade-offs you have made
    - Grades stored as strings only - need custom comparators.

CONSIDER THE ABOVE USE CASE FOR A STUDENT ENROLLING IN A COURSE THAT HAS A PREREQUISITE THAT S/HE HAS PASSED

- Describe using a walkthrough how this use case would be handled in your system: Student enrolling in course with prerequisites passed
    - Student chooses classes: check list of courses stored in main
    - Course checks prerequisites: use `Course.checkPrerequisites(Student studentName)`
    - Student chooses sessions: get sessions from the `Course` class
    - Session checks that no clashes occur: use `Session.checkSessionOverlap(Student)`
    - Student enrols: use `enrol(courseCode, Session)` to add student to Course and to add Session to timetable
- Define a UML sequence diagram corresponding to this walkthrough



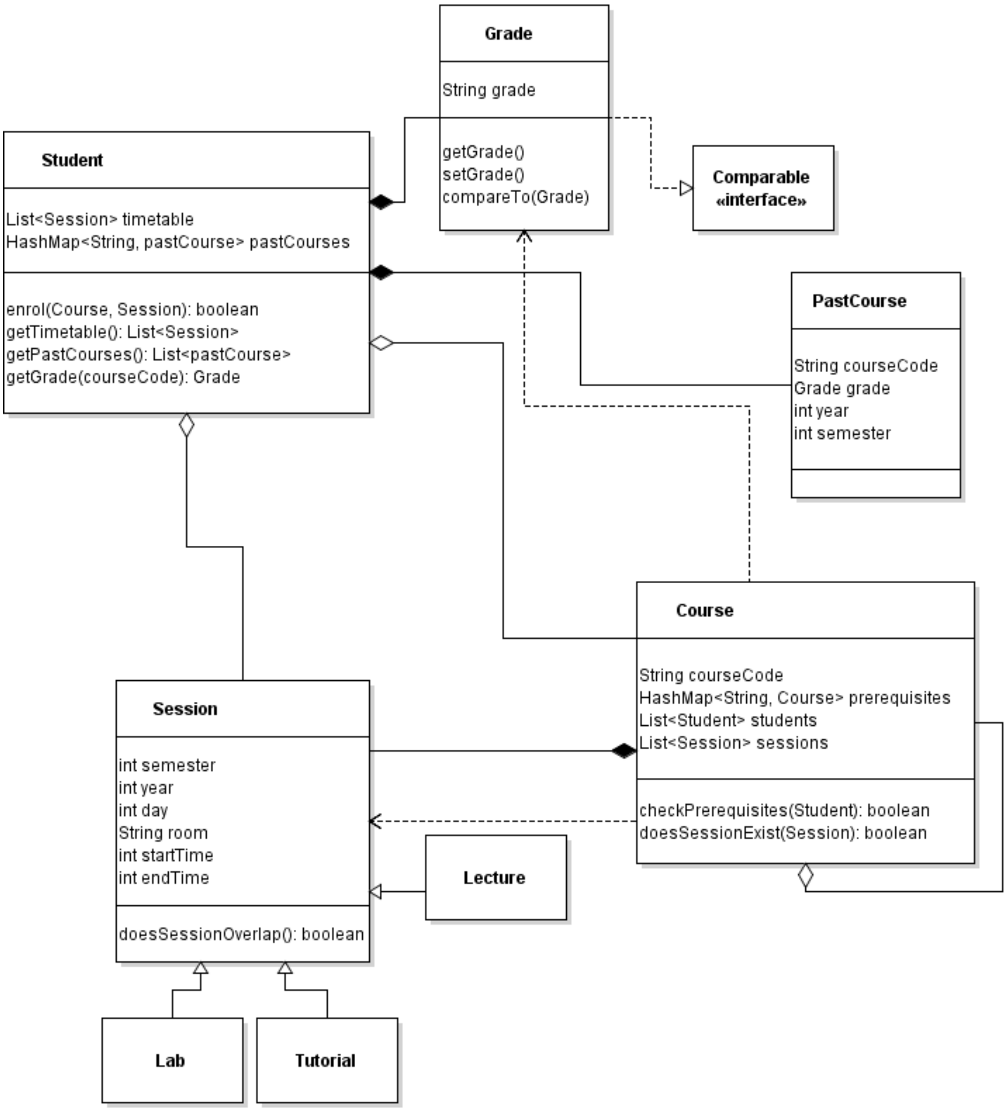
IMPLEMENT YOUR DESIGN USING JAVA, MAKING SURE THAT YOUR CODE CONFORMS TO YOUR DESIGN

```java
import java.util.*;

public class Student {
        private List<Session> timetable;
        private HashMap<String, PastCourse> pastCourses; // string is the course code

        public Student() {
                this.timetable = new ArrayList<Session>();
                this.pastCourses = new HashMap<String, PastCourse>();
        }

        ...

        public boolean enrol(Course c, Session s) {
                if (!c.doesSessionExist(s)) return false;
                if (!c.checkPrerequisites(this)) return false;
                if (s.doesSessionOverlap(this)) return false;

                c.addStudent(this);
                this.addTimetable(s);
                return true;
        }
}

import java.util.*;

public class Course {
        private String courseCode;
        private HashMap<Course, Grade> prerequisites;
        private List<Student> students;
```

```
	private HashSet<Session> sessions;

	public Course(String courseCode) {
		this.courseCode = courseCode;
		this.prerequisites = new HashMap<Course, Grade>();
		this.students = new ArrayList<Student>();
		this.sessions = new HashSet<Session>();
	}

	...

	public boolean doesSessionExist(Session s) {
		return sessions.contains(s);
	}

	public boolean checkPrerequisites(Student s){
		for (Course c: prerequisites.keySet()) {
			if(!s.getPastCourses().containsKey(c.getCourseCode())) return
false;
			if(s.getPastCourses().containsKey(c.getCourseCode()) &&
	s.getGrade(c.getCourseCode()).compareTo(prerequisites.get(c)) == -1) return
false;
		}
		return true;
	}
}

public class PastCourse {
	private String courseCode;
	private Grade grade;
	private int year;
	private int semester;

	public PastCourse(String courseCode, Grade grade, int year, int semester) {
		...
	}

	...
}

public class Session {
	private int semester;
	private int year;
	private String room;
	private int day;
	private int startTime;
	private int endTime;

	public Session(int semester, int year, int day, String room, int startTime,
			int endTime) {
		...
	}

	...

	public boolean doesSessionOverlap(Student s) {
		boolean sessionOverlap = false;
		for (Session n: s.getTimetable()) {
			if (this.overlapsWith(n)) {
				sessionOverlap = true;
			}
		}
		return sessionOverlap;
	}

	public boolean overlapsWith(Session s) {
		if (this.year != s.getYear()) return false;
		if (this.semester != s.getSemester()) return false;
```

```
                if (this.day != s.getDay()) return false;

                if (this.startTime <= s.getStartTime() && s.getStartTime() <
this.endTime) return true;
                if (s.getStartTime() <= this.startTime && this.startTime <
s.getEndTime()) return true;
                return false;
        }
}

public class Grade implements Comparable<Grade>{
        private String grade;

        public Grade(String grade) {
                this.grade = grade;
        }

        ...

        @Override
        /**
         * Order: HD > DN > CR > PS > FL
         */
        public int compareTo(Grade g) {
                int thisGrade = 0;
                int otherGrade = 0;

                if (this.grade.equals("HD”)) thisGrade = 5;
                if (this.grade.equals("DN”)) thisGrade = 4;
                if (this.grade.equals("CR”)) thisGrade = 3;
                if (this.grade.equals("PS”)) thisGrade = 2;
                if (this.grade.equals("FL”)) thisGrade = 1;

                if (g.getGrade().equals("HD”)) otherGrade = 5;
                if (g.getGrade().equals("DN”)) otherGrade = 4;
                if (g.getGrade().equals("CR”)) otherGrade = 3;
                if (g.getGrade().equals("PS”)) otherGrade = 2;
                if (g.getGrade().equals("FL”)) otherGrade = 1;

                if (thisGrade == otherGrade) return 0;
                if (thisGrade > otherGrade) return 1;
                if (thisGrade < otherGrade) return -1;
                else {
                        System.out.println("Invalid Grade ” + this.grade + ” compared
to ” + g.getGrade());
                        return 0;
                }
        }
}
```

- Had to change representation of prerequisites and past courses. Could be avoided by stating data types passed in sequence diagram.



SETS

DEFINE A SET<E> INTERFACE TYPE THAT CAN HANDLE ELEMENTS OF A GENERIC TYPE E

```
import java.util.*;

interface Set<E> extends Iterable<E>{
         // set membership operations
         public void add(E s);
         public void remove(E s);
         public boolean contains (E s);
         // accessors
         public int getSize();
         public Class getType();
         public List<E> getItems();
         // basic operations on sets
         public boolean subset(Set<E> ms);
         public Set<E> intersect(Set<E> ms);
         public Set<E> union(Set<E> ms);
         // other
         public boolean equals(Object o);
         public int hashCode();
         public Iterator<E> iterator();
}
```

DEFINE A CLASS REALIZING THE **SET<E>** INTERFACE THAT USES AN **ARRAYLIST<E>** TO STORE THE ELEMENTS

```java
import java.util.*;

public class MySet<E> implements Set<E>{
        private ArrayList<E> items;
        private final Class<E> type;

        public MySet(Class<E> type){
                this.items = new ArrayList<E>();
                this.type = type;
        }

        @Override
        public int getSize() {
                return items.size();
        }

        @Override
        public Class<E> getType() {
                return this.type;
        }

        @Override
        public Iterator<E> iterator() {
                return items.iterator();
        }

        @Override
        public void add(E s) {
                if (!items.contains(s)) {
                        items.add(s);
                }
        }

        @Override
        public List<E> getItems() {
                return this.items;
        }

        @Override
        public boolean subset(Set<E> ms) {
                Iterator<E> iter = ms.iterator();
                while (iter.hasNext()) {
                        E elem = iter.next();
                        if (!(this.contains(elem))) {
                                return false;
                        }
                }
                return true;
        }

        @Override
        public Set<E> intersect(Set<E> ms) {
                Iterator<E> iter = ms.iterator();
                Set<E> intSet = new MySet<E>(this.type);
                while (iter.hasNext()) {
                        E elem = iter.next();
                        if (this.contains(elem)) {
                                intSet.add(elem);
                        }
                }
                return intSet;
        }

        @Override
        public Set<E> union(Set<E> ms) {
```

```
        Iterator<E> iter1 = this.iterator();
        Iterator<E> iter2 = ms.iterator();
        Set<E> unSet = new MySet<E>(this.type);
        while (iter1.hasNext()) {
                E elem1 = iter1.next();
                unSet.add(elem1);
        }
        while (iter2.hasNext()) {
                E elem2 = iter2.next();
                unSet.add(elem2);
        }
        return unSet;
}

@Override
public boolean equals(Object o) {
        if (o == this) return true; // Check if identical
        if (o == null) return false; // Check if null

        if (!(o instanceof MySet<?>)) return false; // Check if same class

        MySet<?> other = (MySet<?>) o; // Check if same generic type
        if (!other.getType().equals(this.getType())) return false;

        @SuppressWarnings(”unchecked”) // compiler can’t check cast
        MySet<E> o2 = (MySet<E>) other;
        for (E e: o2.getItems()); // causes ClassCastException
        if (other.getSize() != this.getSize()) return false; // check size

        Iterator<E> iter = this.iterator(); // check elements are the same
        while (iter.hasNext()) {
                E elem = iter.next();
                if (!o2.contains(elem)) return false;
        }
        return true;
}

@Override
public int hashCode() {
        return items.hashCode();
}

@Override
public void remove(E s) {
        Iterator<E> iter = this.iterator();
        E elemToRemove = null;
        while (iter.hasNext()) {
                E elem = iter.next();
                if (elem.equals(s)) {
                        elemToRemove = elem;
                }
        }

        if (elemToRemove != null) {
                this.items.remove(elemToRemove);
        }
}

@Override
public boolean contains(E elem2) {
        Iterator<E> iter = this.iterator();
        while (iter.hasNext()) {
                E elem = iter.next();
                if (elem.equals(elem2)) {
                        return true;
                }
        }
        return false;
}
```

```
}
```

- Explain how your code enforces the class invariant that all elements of a set are distinct
    - In the add function, I check if the set already contains the element before adding it.

BY HAVING **SET<E>** EXTEND **ITERABLE<E>**, DEFINE A METHOD ITERATOR() THAT RETURNS AN ITERATOR OVER SETS

```
import java.util.*;

interface Set<E> extends Iterable<E>{
        ...
        public Iterator<E> iterator();
}

import java.util.*;

public class MySet<E> implements Set<E>{
        ...
        @Override
        public Iterator<E> iterator() {
                return items.iterator();
        }
}
```

WRITE A TEST CLASS FOR **SET<E>** THAT USES A **SCANNER** TO READ ELEMENTS FROM AN INPUT FILE, THEN ADD THEM TO VARIOUS SETS (E.G. OF TYPE **STRING)**

```
public void testScanner() {
        ArrayList<Set<Character>> sets = new ArrayList<Set<Character>>();
        try {
                BufferedReader br = new BufferedReader(new FileReader("input.txt"));
                for (String line = br.readLine(); line != null; line = br.readLine()) {
                        Set<Character> set = new MySet<Character>(Character.class);
                        for (int i = 0; i < line.length(); i++) {
                                set.add(line.charAt(i));
                        }
                        sets.add(set);
                }
                br.close();
        } catch (IOException e) {
                e.printStackTrace();
        }
}
```

GRAPHS

- A *directed graph* is a set of nodes and a binary relation over this set (that node *a* is related to node *b* can be represented by an arrow from *a* to *b*)

DEFINE A GENERIC **GRAPH<E>** INTERFACE TYPE THAT HANDLES NODES OF A GENERIC TYPE **E**

```
import java.util.Set;

public interface Graph<E> { // Graph has objects of arbitrary type E
        // Basic graph operations
        //    Accessors (getters)
        public int size();
        public Set<Node<E>> getNodes();
        //    Mutator (setters)
        public void addNode(E a);
        public void removeNode(E a);
        public void addConnection(E from, E to);
        public void removeConnection(E from, E to);
        // Complex graph operations
        public boolean contains(E a); // handy because standard Java term
        public boolean isConnected(E a, E b); // a and b are graph Nodes
}
```

CHOOSE ONE OF THE GRAPH REPRESENTATIONS AND PROVIDE A CLASS THAT IMPLEMENTS THE **GRAPH<E>** INTERFACE TYPE IN THIS WAY

```
import java.util.*;

public class AdjacencyListGraph<E> implements Graph<E>{
        private int size;
        private HashMap<E, Node<E>> nodes;

        public AdjacencyListGraph() {
                super();
                this.size = 0;
                this.nodes = new HashMap<E, Node<E>>();
        }

        @Override
        public int size() {
                return size;
        }

        @Override
        public void addNode(E a) {
                Node<E> n = new Node<E>(a);
                nodes.put(n.getNodeObj(), n);
                size++;
        }

        @Override
        public void removeNode(E a) {
                List<Node<E>> connections = nodes.get(a).getConnections();
                for (Node<E> n: connections) {
                        n.removeConnection(nodes.get(a));
                }
                nodes.remove(nodes.get(a));
                size--;
        }

        @Override
        public void addConnection(E from, E to) {
                nodes.get(from).addConnection(nodes.get(to));
                nodes.get(to).addConnection(nodes.get(from));
        }

        @Override
        public void removeConnection(E from, E to) {
                nodes.get(from).removeConnection(nodes.get(to));
                nodes.get(to).removeConnection(nodes.get(from));
        }

        @Override
        public boolean contains(E a) {
                return nodes.get(a) != null;
        }

        @Override
        public boolean isConnected(E a, E b) {
                return nodes.get(a).isConnected(b);
        }

        public Set<Node<E>> getNodes() {
                return new HashSet<Node<E>>(nodes.values());
        }
}

class Node<E>{
        private E nodeObj;
        private HashMap<E, Node<E>> connections;

        public Node(E nodeObj) {
                super();
                this.nodeObj = nodeObj;
                this.connections = new HashMap<E, Node<E>>();
        }

        public List<Node<E>> getConnections() {
                return new ArrayList<Node<E>>(connections.values());
        }

        public boolean isConnected(E a){
                return connections.containsKey(a);
        }

        public boolean isConnected(Node<E> n) {
                return connections.containsValue(n);
        }

        public void addConnection(Node<E> connectedNode) {
                connections.put(connectedNode.getNodeObj(), connectedNode);
        }

        public void removeConnection(Node<E> connectedNode) {
                connections.remove(connectedNode);
        }

        public E getNodeObj() {
                return nodeObj;
        }
}
```

- If a graph has *n* nodes, an adjacency matrix is an *n* × *n* matrix with entry 1 (or some other data value) in the *i*, *j* element if node *i* is related to node *j*
- The adjacency list is a list whose elements are lists, where for element *i* of the main list, the associated list is of those nodes *j* such that node *i* is related to node *j*

DEFINE SOME SUITABLE CLASS INVARIANTS FOR YOUR IMPLEMENTATION OF THE **GRAPH<E>** INTERFACE TYPE AND SHOW THAT THEY ARE SATISFIED

- Size is always greater than or equal to 0
  - Initially, graph contains no nodes and its size is 0
  - Size increases when a node is successfully added
  - Size increases when a node is successfully removed
- Number of edges is always at most $\frac{n(n-1)}{2}$ for n vertices (when undirected graph is complete)
  - Can only have 1 connection between two nodes

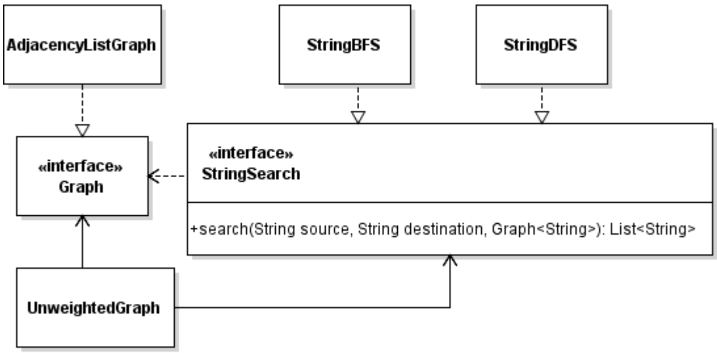
BASIC SEARCH ALGORITHMS

APPLY THE STRATEGY PATTERN SO THAT THE SUCCESSORS OF A NODE ARE SORTED USING AN ANONYMOUS CLASS THAT IMPLEMENTS THE **COMPARATOR** INTERFACE TYPE

```
List<Node<String>> connections = curr.getConnections();
final Collator col = Collator.getInstance();
Comparator<Node<String>> com = new Comparator<Node<String>>() {
        @Override
        public int compare(Node<String> n, Node<String> m) {
                if (col.compare(n.getNodeObj(), m.getNodeObj()) == -1) return -1;
                if (n.getNodeObj().equals(m.getNodeObj())) return 0;
                if (col.compare(n.getNodeObj(), m.getNodeObj()) == 1) return 1;
                System.out.println("Node<String> objects cannot be compared");
        return 0;
        }
};
Collections.sort(connections, com);
```

- This **Comparator** is either in the method that computes the successors of a node or the method that adds those successors to the **Queue** – is either of these options better?
    - The method that compute the children of a node is part of the Node<E> class, so this would reduce encapsulation by asking Node<E> to perform search-related actions.
    - The method that adds children to the queue is the search function, so this option is better.

DRAW A UML CLASS DIAGRAM OF YOUR PROGRAM, MAKING SURE YOUR DESIGN AND CODE CONFORMS TO THE STRATEGY PATTERN



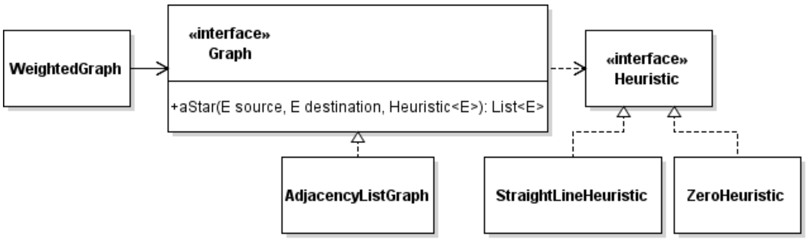
PROBLEM-SOLVING ALGORITHMS

APPLY THE STRATEGY PATTERN SO THAT THE HEURISTIC USED BY A* SEARCH IS PASSED AS A PARAMETER TO AN APPROPRIATE METHOD

```
public interface Heuristic<E> {
        public int distanceLeft(Node<E> source, Node<E> dest);
}
public interface Graph<E> { // Graph has objects of arbitrary type E
        ...
        public List<E> aStar(E source, E destination, Heuristic<E> h);
}
```

- Are there any trade-offs associated with the choice of class or method?
    - Need to code more but more flexible when adding in new strategies.
    - Need to make **Heuristic** object in context.

DRAW A UML CLASS DIAGRAM OF YOUR PROGRAM, MAKING SURE YOUR DESIGN AND CODE CONFORMS TO THE STRATEGY PATTERN



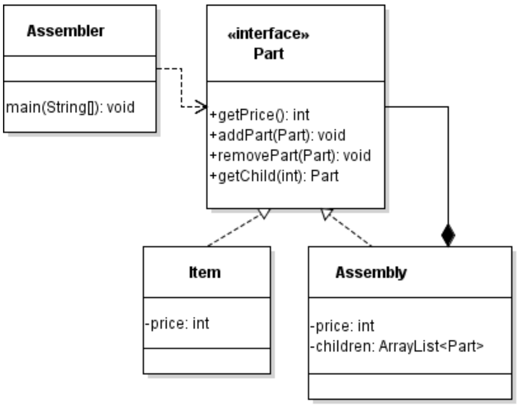
DESIGN PATTERNS

- Each **Item** has a given price, and the price of an **Assembly** is just the total price of all the parts in the assembly

USE THE COMPOSITE PATTERN TO WRITE JAVA CLASSES FOR AN **ASSEMBLY** AND AN **ITEM** WITH METHODS FOR CALCULATING THE TOTAL PRICE OF ANY PART

```java
public interface Part {
        public int getPrice();
        public void addPart(Part p);
        public void removePart(Part p);
        public Part getChild(int index);
}


public class Item implements Part {
        private int price;

        public Item (int price) {
                this.price = price;
        }

        public int getPrice() {
                return this.price;
        }

        @Override
        public void addPart(Part p) {
        }

        @Override
        public void removePart(Part p) {
        }

        @Override
        public Part getChild(int index) {
                return null;
        }
}

import java.util.*;

public class Assembly implements Part {
        private int price;
        private ArrayList<Part> children;

        public Assembly (int price) {
                this.price = price;
                this.children = new ArrayList<Part>();
        }

        public int getPrice() {
                int sumPrices = this.price;
                for (Part p: children) {
                        sumPrices += p.getPrice();
                }
                return sumPrices;
        }

        @Override
        public void addPart(Part p) {
                children.add(p);
        }

        @Override
        public void removePart(Part p) {
                children.remove(p);
        }

        @Override
        public Part getChild(int index) {
                return children.get(index);
        }
}
```

DRAW A UML CLASS DIAGRAM FOR YOUR PROGRAM, MAKING SURE YOUR CODE CONFORMS TO THE COMPOSITE PATTERN



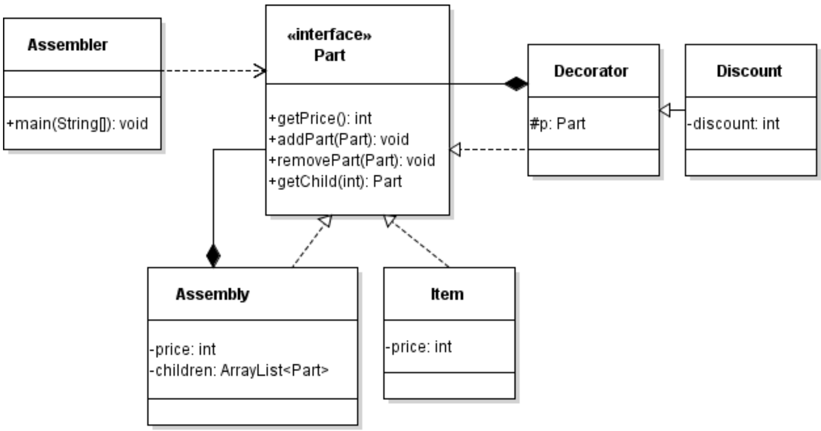
USE THE DECORATOR PATTERN TO ALLOW DISCOUNTED PRICES: DISCOUNTS CAN APPLY TO BOTH BASIC AND ASSEMBLED PARTS, EVEN ALREADY DISCOUNTED PARTS

```
public class Discount extends Decorator {
        private int discount; // discount as a percentage

        public Discount(Part p, int discount) {
                super(p);
                this.discount = discount;
        }

        @Override
        public int getPrice() {
                return p.getPrice() * discount / 100;
        }

        @Override
        public void addPart(Part p) {
                this.p.addPart(p);
        }

        @Override
        public void removePart(Part p) {
                this.p.removePart(p);
        }

        @Override
        public Part getChild(int index) {
                return this.p.getChild(index);
        }
}
```

```
public class Discount extends Decorator {
        private int discount; // discount as a percentage

        public Discount(Part p, int discount) {
                super(p);
                this.discount = discount;
        }

        @Override
        public int getPrice() {
                return p.getPrice() * discount / 100;
        }

        @Override
        public void addPart(Part p) {
```

```
                  this.p.addPart(p);
         }

         @Override
         public void removePart(Part p) {
                  this.p.removePart(p);
         }

         @Override
         public Part getChild(int index) {
                  return this.p.getChild(index);
         }
}
```

EXTEND THE UML CLASS DIAGRAM FOR YOUR PROGRAM, MAKING SURE YOUR CODE CONFORMS TO BOTH THE COMPOSITE AND DECORATOR PATTERNS



CONCURRENCY

```
// Producer implements Runnable
Runnable run1 = new Producer();
Thread thread1 = new Thread(run1);
thread1.start();
```

- Explain why the implementation of the **BoundedQueue** class is not threadsafe
    - Different threads can add and remove from the queue at the same time. As a result, you cannot accurately keep track of the head and the tail of the queue.

USE A RE-ENTRANT LOCK WITH TWO CONDITIONS TO MAKE THE IMPLEMENTATION THREADSAFE

```
import java.util.concurrent.locks.*;

public class BoundedQueue<E> {
   ...
   private final ReentrantLock lock;
   private final Condition spaceAvail;
   private final Condition valueAvail;

   public BoundedQueue(int capacity) {
      ...
      lock = new ReentrantLock();
      spaceAvail = lock.newCondition();
      valueAvail = lock.newCondition();
   }

   public void add(E newValue) throws InterruptedException {
      lock.lock(); // 1 acquire lock
      try {
         if (size == elements.length) { // 2 checks if queue is full
```

```
            spaceAvail.await(); // 3 since queue is full, wait for space available
         }
         ... // add element
         valueAvail.signal(); // 4 signal value available before returning
      } finally {
         lock.unlock(); // 5 release lock when finished
      }
   }

   public E remove() throws InterruptedException {
      lock.lock(); // 1 acquire lock
      try {
         if (size == 0) { // 2 checks if queue is empty
            valueAvail.await(); // 3 since queue is empty, wait for value available
            head = 0;
         }
         ... // remove element
         spaceAvail.signal(); // 4 signal space available before returning
         return r;
      } finally {
         lock.unlock(); // 5 release lock when finished
      }
   }
}
```