**Howard University**

**College of Engineering and Architecture**

**Department of Electrical Engineering & Computer Science**

**Large Scale Programming**

**Fall 2025**

**Midterm Exam**

October 20, 2025

## ****Instructions****

* **Exam Format:**  
  Your examination consists of both **essay** and **programming** problems.
* **Essay Questions:**  
  Complete all essay (rationale) questions **inline in this document**.  
  My preference is **Microsoft Word (.docx)**, but **.txt** or **.pdf** are acceptable alternatives.  
  Upload your completed essay file to your repository under the package:

org.howard.edu.lsp.midterm.doc

You may use **any file name**.

* **Programming Problems:**  
  Each programming problem must be uploaded to your repository using the package specified in the question.  
  For example:

org.howard.edu.lsp.midterm.question1

* **Committing Your Work:**  
  If using a third-party IDE or tool to commit, commit early and often.  
  Do not wait until the end of the exam to push your code.  
  If you encounter problems committing, you may manually upload your code to your repository.  
  If you are unable to commit or upload, you may zip your project and email it to  
  bwoolfolk@whiteboardfederal.com.  
  ⚠️ This will result in a 20% deduction from your final exam score.
* **Citations and References:**  
  You must cite all references for any material obtained from the internet.  
  Any AI-generated content (e.g., ChatGPT conversations) must be included in full.  
  Each package you upload must include a references document corresponding to that package’s content.  
  ⚠️ Failure to provide references will result in a zero for that question.
* **Exam Policy:**  
  This is an OPEN BOOK, OPEN NOTES exam.  
  Collaboration of any kind is strictly prohibited. Any violations will be handled in accordance with **university academic integrity guidelines**.

**Question 1. (20 pts.)**

**Given the following, analyze the class below and answer the below questions. This question does NOT require you to write any code.**

package org.howard.edu.lsp.studentPortalHelper;

import java.io.\*;

import java.time.LocalDate;

import java.time.format.DateTimeFormatter;

import java.util.\*;

public class StudentPortalHelper {

// Data cache (in-memory)

private static final Map<String, String> cache = new HashMap<>();

// GPA calculation

public static double computeGPA(List<Integer> grades) {

if (grades == null || grades.isEmpty()) return 0.0;

int sum = 0;

int count = 0;

for (int g : grades) { sum += g; count++; }

double avg = (double) sum / count;

// simple mapping: 90–100=A=4, 80–89=B=3, etc.

if (avg >= 90) return 4.0;

if (avg >= 80) return 3.0;

if (avg >= 70) return 2.0;

if (avg >= 60) return 1.0;

return 0.0;

}

// CSV export to disk

public static void exportRosterToCsv(String filename, List<String> names) {

try (PrintWriter pw = new PrintWriter(new FileWriter(filename))) {

pw.println("name");

for (String n : names) {

pw.println(n);

}

} catch (IOException e) {

System.err.println("Failed to export roster: " + e.getMessage());

}

}

// Email formatting

public static String makeWelcomeEmail(String studentName) {

return "Welcome " + studentName + "! Please visit the portal to update your profile.";

}

// Date formatting (UI concern)

public static String formatDateForUi(LocalDate date) {

return date.format(DateTimeFormatter.ofPattern("MM/dd/yyyy"));

}

// Payment processing (stub)

public static boolean processTuitionPayment(String studentId, double amount) {

if (amount <= 0) return false;

// pretend to call external gateway...

return true;

}

// Password strength check (security)

public static boolean isStrongPassword(String pwd) {

if (pwd == null || pwd.length() < 8) return false;

boolean hasDigit = false, hasUpper = false;

for (char c : pwd.toCharArray()) {

if (Character.isDigit(c)) hasDigit = true;

if (Character.isUpperCase(c)) hasUpper = true;

}

return hasDigit && hasUpper;

}

// Ad-hoc caching

public static void putCache(String key, String value) {

cache.put(key, value);

}

public static String getCache(String key) {

return cache.get(key);

}

}

**Tasks:**

Using one or more **Arthur Riel heuristics**, analyze whether the StudentPortalHelper class demonstrates **high** or **low cohesion**.  
a) Should a well-designed class have high or low cohesion? Explain and defend your answer. (5 pts.)

b) Based on your analysis, discuss—**only if you believe changes are needed**—how you would reorganize or redesign the class to improve its structure. Your answer should (1) identify the class as having high, low or perfect cohesion and (2) describe a **general approach** to refactoring the class. If you believe the class already has good cohesion, justify why no changes are necessary. (15 pts)

*(If you believe the class already has good cohesion, justify why no changes are necessary.)*

### Part a) High or Low Cohesion

A well-designed class should have **high cohesion**. High cohesion means that all the methods and responsibilities within a class are closely related and focused on a single, well-defined purpose. This aligns with Arthur Riel's heuristics, particularly:

* Heuristic 2.1: "All data and methods in a class should be highly related"
* Heuristic 2.8: "A class should capture one and only one key abstraction"

High cohesion leads to more maintainable, understandable, and reusable code because each class has a clear, singular responsibility.

### Part b) Analysis and Refactoring Approach

The StudentPortalHelper class demonstrates **low cohesion**. According to Riel's heuristics, this class violates the Single Responsibility Principle by mixing multiple unrelated concerns:

1. **Academic calculations** (computeGPA)
2. **File I/O operations** (exportRosterToCsv)
3. **Email formatting** (makeWelcomeEmail)
4. **UI formatting** (formatDateForUi)
5. **Payment processing** (processTuitionPayment)
6. **Security validation** (isStrongPassword)
7. **Caching functionality** (putCache, getCache)

**Refactoring approach:** I would reorganize this class by applying the Single Responsibility Principle and creating separate, cohesive classes:

* GradeCalculator - for GPA computation
* FileExporter - for CSV and other file exports
* EmailService - for email formatting and sending
* DateFormatter or use existing utilities - for date formatting
* PaymentProcessor - for tuition and payment handling
* PasswordValidator - for security validations
* CacheManager - for caching operations

Each new class would have high cohesion, focusing on a single responsibility. This design would improve maintainability, testability, and allow each component to evolve independently.

**Question 2. (20 pts.)**

Write a class AreaCalculator in the package org.howard.edu.lsp.midterm.question2 with the following **overloaded methods**: This should be uploaded to your repo.

// Circle area

public static double area(double radius)

// Rectangle area

public static double area(double width, double height)

// Triangle (base & height) area

public static double area(int base, int height)

// Square (side length) area

public static double area(int side)

**Requirements:**

Each method should compute and return the correct area.

* Circle area: π (use class Math.PI) × r²
* Rectangle area: width × height
* Triangle area: ½ × base × height
* Square area: side²
* For all methods: throw an IllegalArgumentException if any dimension is ≤ 0.

Create a class named Main that invokes each overloaded method **statically** to produce **exactly** the following output:

Circle radius 3.0 → area = 28.274333882308138

Rectangle 5.0 x 2.0 → area = 10.0

Triangle base 10, height 6 → area = 30.0

Square side 4 → area = 16.0

Finally, invoke **at least one** of the area methods with a value that causes an IllegalArgumentException to be thrown.

* Catch the exception using a try/catch block.
* Print an **error message** to System.out. (Any message is fine.)

Briefly (2–3 sentences as a comment in class Main) explain if **overloading** or simply use methods with different names, i.e., rectactangleArea, circleArea, etc..

| **Category** | **Description** | **Points** |
| --- | --- | --- |
| **1. Implementation** | Correct use of **method overloading** (same name, different signatures), correct formulas, and proper exception handling in each method. | **10** |
| **2. Program Behavior** | Main correctly invokes all methods statically, produces the required output exactly, and includes a working exception demonstration. | **6** |
| **3. Conceptual Understanding** | Brief explanation of why or why not overloading is the better design choice. | **4** |

**Question 3.**

**Given the following, answer the below questions.**

**(20 pts.)**

**Given:**

A car manufacturer uses Java software to track current vehicles being built. The UML diagram below shows an excerpt of the current software structure. You should assume the presence of other appropriate fields and methods

**Car**

getTrimLevel()

**Engine**

accelerate()

getFuelLevel()

**Base**

**Sports**

**Luxury**

**Electric**

**Petrol**

Each car can be built to one of three trim levels: Base, Luxury or Sport. They can also be configured with an electric or petrol engine. At various points in the manufacturing process the customer can choose to change the trim level.

**Task:**

1. Explain in detail why the current structure does or does not support this. (10 pts.)
2. Describe how to refactor the structure to allow trim-level change for a car to dynamically change. Hint: How would you modify Car to use composition to solve the problem? (10 pts.)

**Part a) Does the current structure support trim-level changes?**

The current structure **does not** support changing trim levels during the manufacturing process. The problem lies in the use of inheritance for trim levels (BaseCar, LuxuryCar, SportCar). Once a car object is instantiated as a specific subclass (e.g., LuxuryCar), it cannot change its type to another subclass at runtime.

This is a fundamental limitation of inheritance in object-oriented programming: an object's class is fixed at instantiation. If a customer wants to change from Luxury to Sport trim, you would need to:

1. Create a new SportCar object
2. Copy all the relevant data from the LuxuryCar object
3. Discard the original object

This approach is inefficient, error-prone, and violates the principle that an object should maintain its identity throughout its lifecycle.

**Part b) Refactoring using Composition**

To allow dynamic trim-level changes, refactor using the **Strategy Pattern** with composition:

1. **Create a TrimLevel interface or abstract class**:
   * Define common trim-level behaviors (e.g., getFeatures(), getPrice())
2. **Create concrete TrimLevel implementations**:
   * BaseTrim, LuxuryTrim, SportTrim classes implementing TrimLevel
3. **Modify Car class to use composition**:
   * Add a TrimLevel trimLevel field to Car
   * Add a setTrimLevel(TrimLevel trim) method to allow changes
   * Delegate trim-specific behavior to the TrimLevel object
4. **Keep Engine as a composition field** (already good design)

This design allows a Car object to change its trim level at any time by simply calling setTrimLevel(new SportTrim()). The car maintains its identity while changing its behavior dynamically.

**Question 4. (30 pts.)**

Design and implement a small **smart-campus device** system showing both **class inheritance** (concrete classes extend a common abstract class) and **interface implementation**.

**1) Abstract Base Class — Device**

**The following Device class is partially implemented for you.  
You must not modify this code, but you will use it in your subclasses:**

package org.howard.edu.lsp.midterm.question4;

public abstract class Device {

private String id;

private String location;

private long lastHeartbeatEpochSeconds;

private boolean connected;

// PROVIDED CONSTRUCTOR

public Device(String id, String location) {

if (id == null || id.isEmpty() || location == null || location.isEmpty()) {

throw new IllegalArgumentException("Invalid id or location");

}

this.id = id;

this.location = location;

this.lastHeartbeatEpochSeconds = 0;

this.connected = false;

}

public String getId() {

return id;

}

public String getLocation() {

return location;

}

public long getLastHeartbeatEpochSeconds() {

return lastHeartbeatEpochSeconds;

}

public boolean isConnected() {

return connected;

}

protected void setConnected(boolean connected) {

this.connected = connected;

}

public void heartbeat() {

this.lastHeartbeatEpochSeconds = System.currentTimeMillis() / 1000;

}

public abstract String getStatus();

}

**You will extend this class** in your DoorLock, Thermostat, and Camera implementations.  
All subclasses must call super(id, location) in their constructors.

**2) Capability Interfaces (behaviors only)**

**Networked**

void connect();

void disconnect();

boolean isConnected();

Behavior:

* connect() brings the device online by setting connected = true.
* disconnect() sets connected = false.
* isConnected() reports the current connection state.  
  (Concrete classes may satisfy this using Device’s protected setter and public getter.)

**BatteryPowered**

int getBatteryPercent(); // 0..100

void setBatteryPercent(int percent);

Behavior:

* getBatteryPercent() returns current battery %.
* setBatteryPercent(int) updates it; throw IllegalArgumentException if outside 0..100 inclusive.

**3) Concrete Devices (must extend Device and implement interfaces)**

**All fields must be private. Implement methods exactly as specified.**

1. **DoorLock — extends Device, implements Networked, BatteryPowered**

**Private fields**

private int batteryPercent;

**Constructor**

public DoorLock(String id, String location, int initialBattery)

* Call super(id, location).
* Initialize battery by calling setBatteryPercent(initialBattery) (enforces 0..100).

**Implemented methods**

// Networked

@Override public void connect() { setConnected(true); }

@Override public void disconnect() { setConnected(false); }

@Override public boolean isConnected() { return super.isConnected(); }

// BatteryPowered

@Override public int getBatteryPercent() { return batteryPercent; }

@Override public void setBatteryPercent(int percent) {

if (percent < 0 || percent > 100) throw new IllegalArgumentException("battery 0..100");

this.batteryPercent = percent;

}

// Status

@Override public String getStatus() {

String connStatus = isConnected() ? "up" : "down";

return "DoorLock[id=" + getId() + ", loc=" + getLocation() +

", conn=" + connStatus + ", batt=" + batteryPercent + "%]";

}

**B) Thermostat — extends Device, implements Networked**

**Private fields**

private double temperatureC;

**Constructor**

public Thermostat(String id, String location, double initialTempC)

* Call super(id, location).
* Initialize temperatureC to initialTempC.

**Accessors**

public double getTemperatureC();

public void setTemperatureC(double temperatureC);

**Implemented methods**

// Networked

@Override public void connect() { setConnected(true); }

@Override public void disconnect() { setConnected(false); }

@Override public boolean isConnected() { return super.isConnected(); }

// Status

@Override public String getStatus() {

String connStatus = isConnected() ? "up" : "down";

return "Thermostat[id=" + getId() + ", loc=" + getLocation() +

", conn=" + connStatus + ", tempC=" + temperatureC + "]";

}

**C) Camera — extends Device, implements Networked, BatteryPowered**

**Private fields**

**private int batteryPercent;**

**Constructor**

public Camera(String id, String location, int initialBattery)

* Call super(id, location).
* Initialize battery by calling setBatteryPercent(initialBattery).

**Implemented methods**

// Networked

@Override public void connect() { setConnected(true); }

@Override public void disconnect() { setConnected(false); }

@Override public boolean isConnected() { return super.isConnected(); }

// BatteryPowered

@Override public int getBatteryPercent() { return batteryPercent; }

@Override public void setBatteryPercent(int percent) {

if (percent < 0 || percent > 100) throw new IllegalArgumentException("battery 0..100");

this.batteryPercent = percent;

}

// Status

@Override public String getStatus() {

String connStatus = isConnected() ? "up" : "down";

return "Camera[id=" + getId() + ", loc=" + getLocation() +

", conn=" + connStatus + ", batt=" + batteryPercent + "%]";

}

**4) Provided Driver**

**Do not modify this file. Your classes must compile and run with it unchanged.**

package org.howard.edu.lsp.midterm.question4;

import java.util.\*;

public class Main {

public static void main(String[] args) {

Device lock = new DoorLock("DL-101", "DormA-1F", 85);

Device thermo = new Thermostat("TH-202", "Library-2F", 21.5);

Device cam = new Camera("CA-303", "Quad-North", 72);

// === Invalid battery test ===

System.out.println("\n== Exception test ==");

try {

Device badCam = new Camera("CA-404", "Test-Lab", -5);

System.out.println("ERROR: Exception was not thrown for invalid battery!");

} catch (IllegalArgumentException e) {

System.out.println("Caught expected exception: " + e.getMessage());

}

// === Heartbeat demonstration ===

System.out.println("\n== Heartbeat timestamps BEFORE ==");

for (Device d : Arrays.asList(lock, thermo, cam)) {

System.out.println(d.getId() + " lastHeartbeat=" + d.getLastHeartbeatEpochSeconds());

}

lock.heartbeat();

thermo.heartbeat();

cam.heartbeat();

System.out.println("\n== Heartbeat timestamps AFTER ==");

for (Device d : Arrays.asList(lock, thermo, cam)) {

System.out.println(d.getId() + " lastHeartbeat=" + d.getLastHeartbeatEpochSeconds());

}

// === Base-class polymorphism ===

List<Device> devices = Arrays.asList(lock, thermo, cam);

System.out.println("\n== Initial status via Device ==");

for (Device d : devices) {

System.out.println(d.getStatus());

}

// === Interface polymorphism: Networked ===

System.out.println("\n== Connect all Networked ==");

for (Device d : devices) {

if (d instanceof Networked) {

((Networked) d).connect();

}

}

// === Interface polymorphism: BatteryPowered ===

System.out.println("\n== Battery report (BatteryPowered) ==");

for (Device d : devices) {

if (d instanceof BatteryPowered) {

BatteryPowered bp = (BatteryPowered) d;

System.out.println(d.getClass().getSimpleName() + " battery = " + bp.getBatteryPercent() + "%");

}

}

// === Final status check ===

System.out.println("\n== Updated status via Device ==");

for (Device d : devices) {

System.out.println(d.getStatus());

}

}

}

**5) Brief Rationale (2–4 sentences)**

* Why is Device defined as an abstract class?
* How do the Networked and BatteryPowered interfaces add behavior to your concrete classes?
* Is this design an example of *multiple inheritance* in Java? Explain why or why not.

## Question 4 - Brief Rationale

**Why is Device defined as an abstract class?**

Device is defined as an abstract class because it provides shared implementation code (fields like id, location, connected state, and methods like heartbeat()) that all devices need, while also enforcing that each specific device type must implement its own getStatus() method through the abstract method declaration. This combination of providing partial implementation while requiring subclass-specific behavior makes abstract classes ideal - we avoid code duplication while ensuring each device type defines its unique status format.

**How do the Networked and BatteryPowered interfaces add behavior to your concrete classes?**

The Networked and BatteryPowered interfaces add behavior through a "mix-and-match" capability pattern - each interface defines a contract for optional device capabilities that concrete classes can selectively implement based on their actual features. For example, DoorLock and Camera implement both interfaces (they need network connectivity and have batteries), while Thermostat only implements Networked (it's wall-powered, not battery-powered). This design allows flexible composition of behaviors without forcing all devices to have all capabilities.

**Is this design an example of multiple inheritance in Java? Explain why or why not.**

This is NOT true multiple inheritance in Java - it's a combination of single class inheritance (each device extends only one class: Device) with multiple interface implementation. Java explicitly prohibits multiple class inheritance to avoid the "diamond problem" where conflicting implementations could be inherited from multiple parent classes. Instead, Java allows classes to implement multiple interfaces, which only define method signatures (contracts) without implementation conflicts, providing the flexibility of multiple inheritance while maintaining code safety and clarity.

**Grading (30 pts)**

| **Category** | **Description** | **Points** |
| --- | --- | --- |
| **Implementation** | Correct use of inheritance and interfaces; meets all required method signatures and behaviors; uses the provided Device constructor; correctly implements Networked and BatteryPowered; uses setConnected(boolean) properly; validates inputs. | **15** |
| **Program Behavior** | Code compiles and runs with the provided Main.java unchanged; heartbeat behavior works; base-class and interface polymorphism demonstrated; exception thrown for invalid battery input; getStatus() output matches required formats. | **9** |
| **Rationale** | Clear, thoughtful, and specific answers to the four questions above. References to the student's own code are present. Shows conceptual understanding of abstraction, interface-based behavior, and multiple inheritance in Java. | **6** |

**Question 5 (10 pts)**  
**Reflection on AI Use in Learning and Problem Solving**

Discuss your personal experience using **AI tools** (such as ChatGPT, GitHub Copilot, or others) before and during this course.  
In your response, address the following points:

1. How have you used AI to support your learning or programming in this course?
2. What benefits or limitations did you encounter?
3. Looking ahead, how do you expect AI to influence the way you solve problems **academically or professionally**?

Your answer should be **1–2 well-developed paragraphs.**

## Question 5 - Reflection on AI Use in Learning and Problem Solving

I've integrated AI tools, primarily ChatGPT and GitHub Copilot, as complementary learning resources throughout this course, treating them as intelligent reference materials rather than solution generators. When encountering new design patterns or struggling with Java syntax, I use AI to break down complex concepts into digestible explanations with concrete examples - for instance, understanding the nuances between abstract classes and interfaces became clearer through interactive Q&A sessions where I could immediately test edge cases and misconceptions. I've found AI particularly valuable for debugging cryptic error messages, exploring alternative implementation approaches, and generating test cases I might not have considered. However, I've learned to approach AI suggestions critically; I've encountered instances where the generated code was syntactically correct but violated design principles we've studied, or where solutions were overcomplicated for the actual requirements. The key limitation is that AI lacks context about our specific course objectives and can sometimes provide "textbook" solutions that don't align with the particular constraints or learning goals of an assignment.

Looking forward, I see AI fundamentally shifting from a nice-to-have tool to an essential component of the professional development workflow, much like IDEs revolutionized coding from simple text editors. Academically and professionally, I expect to use AI as a sophisticated pair-programming partner for rapid prototyping, exploring multiple solution architectures simultaneously, and handling boilerplate code generation, allowing me to focus on higher-level system design and business logic. The critical skill will be developing strong "AI literacy" - knowing how to prompt effectively, when to trust versus verify AI output, and maintaining the fundamental understanding to explain and modify any AI-assisted code. Rather than replacing the need for deep technical knowledge, AI will likely raise expectations for developer productivity and code quality, making it crucial to understand not just how to use these tools, but also their limitations and the importance of maintaining core problem-solving abilities independent of AI assistance.