

## Assignment #2 [8 Marks]

Due Date	21 April 2022 23:59
Course	[M1522.000600] Computer Programming
Instructor	Jae W. Lee

- You are allowed to discuss with fellow students to understand the questions better, but your code must be **SOLELY YOURS**. You **MUST NOT** show your code to anyone else, or vice versa.
- We will use the automated copy detector to check the possible plagiarism of the code between the students. The copy checker is reliable so that it is highly likely to mark a pair of code as the copy even though two students quickly discuss the idea without looking at each other's code. Of course, we will evaluate the similarity of a pair compared to the overall similarity for the entire class.
- We will do the manual inspection of the code. In case we doubt that the code may be written by someone else (outside of the class like github), we reserve the right to request an explanation about the code. We will ask detailed Problems that cannot be answered if the code is not written by yourself.
- If one of the above cases happens, you will get 0 marks for the assignment and may get a further penalty. Please understand that we will apply these methods for the fairness of the assignment.
- Download and unzip "HW2.zip" file from the newetl. The file contains skeleton codes for Question 1 (in the "problem1" directory) and Question 2 (in the "problem2" directory).
- Do not modify the overall directory structure after unzipping the file, and fill in the code in appropriate files. It is okay to add new directories or files if needed.
- **Do NOT use ANY external libraries or methods** (even `java.util.*` or `collection` framework) which are not already imported. All "import" you need is already written in the skeleton code. But you can use any method which doesn't need additional import (e.g. `java.lang.*` such as `java.lang.Object` class) such as `Math.random()` or `String.split()` or `toString()`. But check whether the method is supported by the JAVA version we use (11.0.14) before using it. If the method does not work on 11.0.14 version, you could get 0 score. Please don't ask about the allowed methods or libraries, just do based on this paragraph.

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## Notes

- Feel free to add new classes if necessary.
- Feel free to add member attributes (don't modify the access modifiers of given attributes) or modify implementations of methods of the given classes in the skeleton code unless we instruct otherwise.
- However, **DO NOT** modify the package name, the signature of the given methods (i.e., return type, method name, and parameter types) or additionally extend class or implement interface to classes. **The exact given package name and signature of methods will be used for the final evaluation.** We don't have responsibility for disadvantages from modifying skeleton code.
- If you have any questions about whether you should take care of a specific corner case, contact TA through Slack.
- Test cases are introduced as Test.java. Please test your code with this testbench before submission. Of course, we will replace testbench with new Test.java with more complicated cases when we score your codes.
- Description document is pretty long, but don't be afraid! It is long due to the kind explanation of the code step by step. Keep calm and read carefully, then it will not be that difficult.

## Submission Guidelines

1. For submission, compress the entire "problem1" and "problem2" directory in a single zip file.

- The directory structure of your submitted file (after unzipping) should look like the following. **When you extract the zip file, there must be the 20xx-xxxxx/ directory.**
- Name the compressed file "20XX-XXXXX.zip" (your student ID).
- Submit your code on the neweTL.
- Please submit only .java files. Delete files or folders like .iml / MACOSX/ DS\_store / out / .idea before submit.
- Double-check if your final zip file is properly submitted.
- Note that **you will get 0 marks for the wrong submission format.**

#### Submission Directory Structure (Directories or Files can be added)

- Inside 20xx-xxxxx/ directory, there should be problem1/ and problem2/ directory.
- Refer to the screenshot below.

Directory Structure of Problem 1	Directory Structure of Problem 2
<pre> problem1/ ├── src/ │   ├── security/... │   ├── bank/ │   │   ├── event/... │   │   ├── MobileApp.java │   │   ├── Bank.java │   │   └── BankAccount.java │   └── Test.java </pre>	<pre> problem2/ ├── src/ │   ├── map/ │   ├── player/ │   │   ├── animal/ │   │   │   ├── Rabbit.java │   │   │   ├── Turtle.java │   │   └── human/ │   │       ├── Runner.java │   │       └── Swimmer.java │   └── simulator/ │       ├── Map.java │       └── Simulator.java └── Test.java </pre>



## Question 1: Secure Banking [4 Marks]

**Objectives:** Develop a secure mobile banking service that supports financial transactions like deposit, withdrawal, and transfer with secure transactions.

**Descriptions:** “Bank of SNU” plans to open an online banking service to enable a range of financial transactions through a mobile banking application. You are asked to implement this service with Java applying the Object-Oriented Programming (OOP) concept.

The problem consists of three parts. Firstly, you will implement a simple form of `Bank` class that supports various transactions. Secondly, you will implement a `MobileApp` class and emulate secure transactions between `MobileApp` and `Bank` classes. Finally, you will implement a compensation transaction for the hacked account. Note: we will not implement a real mobile app nor communication across different devices; they are just conceptual entities. All the implementations will be done within a single Java program.

### Question 1.1: Bank Account [1 Mark]

**Objective:**

- Implement six member methods of the `BankAccount` class in the `bank` package (i.e., `BankAccount`, `authenticate`, `deposit`, `withdraw`, `receive`, `send`)
- Implement six member methods of the `Bank` class in the `bank` package (i.e., `createAccount`, `deposit`, `withdraw`, `transfer`, `getEvents`, `getBalance`)

**Descriptions:** On creating a personal savings account, a `BankAccount` object is created to manage the account information of a client. The `Bank` class is responsible for storing and managing multiple `BankAccount` objects for all clients. A client can `createAccount`, `deposit`, `withdraw` and `transfer` from his/her account through a `Bank` object; a client cannot directly access the `BankAccount` object.

Event Class Descriptions

- Use the **provided** `Event` class and its subclasses in the `bank.event` package to implement `Bank` and `BankAccount` classes. `Event` classes are used to keep track of the history of transactions. Upon each transaction, an appropriate `Event` object is created and stores the information regarding the transaction.
- There are four subclasses of the `Event` class: `DepositEvent`, `WithdrawEvent`, `SendEvent`, and `ReceiveEvent`.

- Please **DO NOT** modify source codes of the `Event` class and four subclasses of the `Event` class. We would stick to what we have provided for the final evaluation, even if you modified the package.

### BankAccount Class Specifications

Implement the following methods to handle different transactions. The class will also manage the history of transactions using the `Event` class described above; upon each transaction, an `Event` object is created and stored in the `events` array. Assume that the event array can store up to 100 events, and no more than 100 events are stored per `BankAccount`. You don't have to consider  $(100+\alpha)$  events per `BankAccount` case.

- `BankAccount(String id, String password, int balance)`
  - Construct the `BankAccount` object and initialize its `id`, `password` and `balance` attributes with the given parameter values.
- `boolean authenticate(String password)`
  - Check if the account's password is equal to the given password.
  - Return true if and only if the password strings are exactly equal.
    - "password" "password" are different due to space : return false
- `void deposit(int amount, int transId)`
  - Add the amount to the balance, and add a `DepositEvent` object to the `events` array.
  - There will be no corner case with the amount value less than 0.
- `boolean withdraw(int amount, int transId)`
  - Check if the balance is larger than or equal to the amount. If yes, subtract the amount from the balance, add a `WithdrawEvent` object to the `events` array, and return true.
  - Otherwise, return false.
  - There will be no corner case with the amount value less than 0.
- `void receive(int amount, int transId)`
  - Add the balance by the amount, and add a `ReceiveEvent` object to the `events` array.
  - There will be no corner case with the amount value less than 0.
- `boolean send(int amount, int transId)`
  - Check if the balance is larger than or equal to the amount. If yes, subtract the amount from the balance, add a `SendEvent` object to the `events` array, and return true.
  - Otherwise, return false.

- There will be no corner case with the amount value less than 0.

## Bank Class Specifications

Implement the following member methods. You will need to use appropriate member methods of the `BankAccount` class (Consider implementing `BankAccount` Class first!). All methods except for `createAccount` require a password authentication prior to the corresponding transaction.

Assume that the maximum number of bank accounts that a bank manages is 100.

- `public void createAccount(String id, String password)` and `public void createAccount(String id, String password, int initBalance)`
  - Create a `BankAccount` object with the given account id, password, and the initial balance.
  - If the initial balance is not given, set the initial balance to 0.
  - If the given id already exists in the bank, do not create the account.(ignore the request)
  - The negative `initBalance` is not considered for the final evaluation.
- `public boolean deposit(String id, String password, int amount, int transId)`
  - Authenticate the client with the id and password.
  - If the authentication is not successful or there is no account with the given id, do nothing, and return false.
  - If the authentication is successful, add the `amount` to the balance and return true.
  - Use the `deposit` method of the `BankAccount` class.
- `public boolean withdraw(String id, String password, int amount, int transId)`
  - Authenticate the client with the id and password.
  - If the authentication is not successful or there is no account with the given id, do nothing, and return false.
  - If the authentication is successful, subtract the `amount` from the account's balance.
  - Return false if there is not enough balance to withdraw. Otherwise return true.
  - Use the `withdraw` method of the `BankAccount` class.
- `public boolean transfer(String sourceId, String password, String targetId, int amount, int transId)`
  - Authenticate the source account with the `sourceId` and `password`.
  - If there is no account with the given `sourceId` or `targetId`, do nothing, and return false.
  - If the authentication is not successful, do nothing, and return false.
  - If the authentication is successful, transfer the `amount` to the `targetId`'s account.
  - Return false if the amount is larger than the balance of the source account
  - Use the `send` and `receive` method of the `BankAccount` class.
  - Since transfer is one transaction request, `transIds` of `send` and `receive` method in `transfer` method are same.

- `public Event[] getEvents(String id, String password)`
  - Authenticate the client with the `id` and the `password`.
  - Return null if the authentication fails or there is no account with the given `id`.
  - Return the array of `Events` that were **recorded** upon the `deposit`, `withdraw`, and `transfer` method calls.
    - The returned array should not contain null.
    - Return null if there has been no event since creation of the account.
    - More recent `Events` must be located **after** the older `Events` in the array.
- `public int getBalance(String id, String password)`
  - Authenticate the client with the `id` and the `password`.
  - Return the balance of the corresponding account. Return `-1` if the authentication fails.

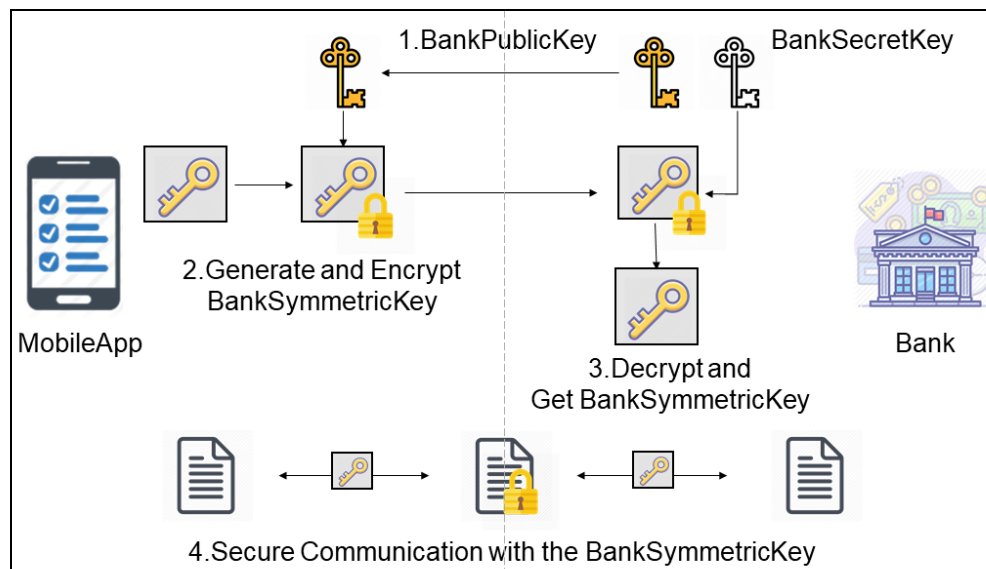
## Question 1.2: Secure Mobile Banking [1 Mark]

### Objectives:

- Implement four methods (`sendSymKey`, `deposit`, `withdraw`, and `processResponse`) of the `MobileApp` class in the `bank` package.
- Implement two methods (`processRequest` and `fetchSymKey`) of the `Bank` class in the `bank` package.

**Descriptions:** For Question 1.1 and 1.2, we assumed scenarios where customers directly access the bank management system through the `Bank` class. Now, we would like to help the customers to access the banking service through a mobile application (represented with the `MobileApp` class). Note that this is not a real mobile application; rather, it is a java class emulating the behavior of a mobile application. In addition, to make the banking service secure and prevent hackers from manipulating the client's financial transactions, we would like to enable secure transactions between the `MobileApp` object and the `Bank` object; again, we are not really implementing secure networking, but just emulating secure transactions to practice the OOP concept.

Before you implement the methods, you will need to understand a new concept, a 'handshake protocol' (See. <https://youtu.be/sEkw8ZcxtFk?t=166>), which is a standard way to establish a secure transaction channel. The following figure and texts describe key steps of the protocol.



When a **MobileApp** needs to communicate with a **Bank** for secure transactions, it first creates a secure channel through the following 'handshaking' steps.

1. The **Bank** generates two keys: **BankPublicKey** and **BankSecretKey**. It sends **BankPublicKey** to the **MobileApp**, and stores the **BankSecretKey** internally.
2. The **MobileApp** generates **BankSymmetricKey** and encrypts it with the received **BankPublicKey**. As a result, the **Encrypted<BankSymmetricKey>** is created and transmitted to the **Bank**.
3. The **Bank** decrypts the received **Encrypted<BankSymmetricKey>** with the **BankSecretKey** (created in Step 1) to obtain the **BankSymmetricKey**.

Once the handshake is complete, both the **Bank** and the **MobileApp** have a shared **BankSymmetricKey**, which is used to encrypt and decrypt the data for the subsequent transactions. The **MobileApp** and the **Bank** can use the **Encrypted<T>** class to encrypt and decrypt the data with **BankSymmetricKey**, respectively.

In the skeleton code, the 'handshake protocol' is implemented via the **handshake** method of the **Protocol** class in the **security** package. For a **MobileApp** to send transaction requests to a **Bank**, it first needs to perform **Protocol.handshake**, and then uses the **Protocol.communicate** method to conduct follow-up transactions. Note: we will test your submission with these two methods of **Protocol** class.

When you look at the **handshake** and **communicate** methods, you can see that they are



implemented by calling adequate member methods of the `MobileApp` class and the `Bank` class. Thus, the main goal of this problem is to fill in these member methods to make the handshake and communicate methods fully working.

Before jumping into the implementation, you may want to carefully look at the three provided classes, the `Protocol` class, the `Encrypted<T>` class and the `Message` class. We already implemented these three classes, and you **DO NOT** have to modify them.

### Protocol Class Descriptions

This class is responsible for enabling i) the handshake between a mobile application and a bank and ii) secure communications between the mobile application and the bank for subsequent transactions.

- `public static void handshake(MobileApp mobileApp, Bank bank)`
  - This method implements the handshake protocol (Step 1-3).
  - It invokes the `bank.getPublicKey` (Step 1), `mobileApp.sendSymKey` (Step 2), `bank.fetchSymKey` (Step 3) in a sequence.
- `public static boolean communicate(Deposit deposit, MobileApp mobileApp, Bank bank, int amount)`
  - This method enables a secure deposit transaction through secure communication.
  - The first argument is used to identify the type of the transaction.
  - In this method, `mobileApp.deposit`, `bank.processRequest`, and `mobileApp.processResponse` are invoked in sequence. It is your job to implement three methods to make the secure deposit successful.
- `public static boolean communicate(Withdraw withdraw, MobileApp mobileApp, Bank bank, int amount)`
  - This method enables the secure withdrawal transaction through secure communication.
  - The first argument is used to identify the type of the transaction.
  - In this method, `mobileApp.withdraw`, `bank.processRequest`, and `mobileApp.processResponse` are invoked in sequence. It is your job to implement three methods to make the secure withdrawal successful.
- `public static boolean communicate(Compensate compensate, MobileApp mobileApp, Bank bank, String questionAnswer, int[] transIdList)`
  - This method enables the secure compensation transaction through secure communication. (Problem 1.3)
  - The first argument is used to identify the type of the transaction.

- In this method, `mobileApp.requestCompensate`, `bank.processRequest`, and `mobileApp.processResponse` are invoked in sequence. It is your job to implement three methods to make the secure compensation successful.

### Encrypted<T> Class Descriptions

This class is responsible for encrypting and decrypting T-typed data using a proper key.

- `public Encrypted(T obj, [BankSymmetricKey/BankPublicKey] key)`
  - This method emulates the encryption of the given `obj` with the `key`. Specifically, it stores a T object as a private attribute, which can be only accessed with the corresponding key.
  - The key could be either a `BankSymmetricKey` object (used for transactions) or `BankPublicKey` object (used for handshake).
- `public T decrypt( [BankSymmetricKey/BankSecretKey] key)`
  - This method emulates the decryption of the stored encrypted object. Specifically, it retrieves the stored T object only if the `key` is the right key.
  - The `key` could be either a `BankSymmetricKey` object (used for transactions) or `BankSecretKey` object (used for handshake).
  - The data encrypted with a `BankPublicKey` object can only be decrypted with the **paired** `BankSecretKey` object.
  - The data encrypted with a `BankSymmetricKey` object can only be decrypted with the **same** `BankSymmetricKey` object.
  - If the `key` does not match, it returns null, indicating the failure of the decryption.

### Message Class Descriptions

This provided class is used to format the information of a transaction when a `MobileApp` makes a transaction request to the `Bank`. The class has the following attributes. Also, it provides a constructor to initialize the attributes and getters to access individual attributes.

- `String requestType`: The type of the transaction request. It can be either “deposit” or “withdraw” or **“compensate”**.
- `String id, password`: The authentication information of the customer.
- `int amount`: The argument for the deposit and withdraw calls.
- `String qna` : Question and answer for secondary authentication.
- `int transId`: Identifier for each transaction. This is a positive integer number and assigned to each transaction from one.
- `int[] transIdList`: Requested transaction Id list for compensation in Problem 1.3.

Now, you are ready to implement the methods of the `MobileApp` class and the `Bank` class. See the specifications below for details. Note: Please **DO NOT** modify the source code in the security package. We will use the original security package for the final evaluation.

## MobileApp Class Specifications

Implement the following methods to support secure transactions. Every `MobileApp` object is initialized with a unique `String AppId` generated by the `randomUniqueStringGen` method. `MobileApp` server manages every transaction and allocates `transId` for each transaction. We emulate this briefly by the static attribute `curTransId`. `curTransId` indicates current transaction `Id` and you increase this variable by one when you create a `deposit` or `withdraw` `Message` object. `curTransId` is always a positive number and allocated consecutively from one.

- `public MobileApp(String id, String password)`
  - This method is provided.
  - Sign in to the mobile application with the given `id` and `password`.
  - Sets the member attribute `id` and `password`.
- `public Encrypted<BankSymmetricKey> sendSymKey(BankPublicKey publickey)`
  - This method performs Step 2 of the handshake protocol, i.e., encrypting a `BankSymmetricKey` with the `publickey` and sending it to the bank.
  - You need to generate a random string with the `randomUniqueStringGen` method, and create a `BankSymmetricKey` object with it.
    - You should store the created `BankSymmetricKey` object for further communications.
  - Then, you need to encrypt the created `BankSymmetricKey` object with the given `publickey` and return the `Encrypted<BankSymmetricKey>`.
- `public Encrypted<Message> deposit(int amount)`
  - This method constructs an encrypted message to deposit the money. The encrypted message is used by the `processRequest` method of the `Bank` class.
  - You should create a `Message` object with the `String` “deposit”(case sensitive), `id`, `password` and `amount` and `transId`. `TransId` is the identifier code for each transaction and the `MobileApp` class manages it. Note that `curTransId` is a static member. It increases by one after the first transaction message is constructed. `TransId` should be a positive integer number.
  - Then, you need to encrypt the `Message` object with the `BankSymmetricKey` object (generated by the `sendSymKey`), and return the `Encrypted<Message>`.
- `public Encrypted<Message> withdraw(int amount)`
  - This method constructs an encrypted message to withdraw the money. The encrypted message is used by the `processRequest` method of the `Bank` class.
  - You should create a `Message` object with the `String` “withdraw”(case sensitive), `id`, `password` and `amount` and `transId`. `TransId` is the identifier code for each transaction and the `MobileApp` class manages it. Note that `curTransId` is a static

member. It increases by one after the first transaction message is constructed. TransId should be a positive integer number.

- Then, you need to encrypt the Message object with the BankSymmetricKey object (generated from the sendSymKey), and return the Encrypted<Message>.
- public boolean processResponse(Encrypted<Boolean> obj)
  - This method decrypts the encrypted response from the Bank.
  - Return false if the obj is null.
  - Otherwise, decrypt the obj with the BankSymmetricKey object (generated from the sendSymKey). If decryption fails, return false, otherwise return the value of the decrypted output.

## Bank Class Specifications

Implement the following two member methods: fetchSymKey and processRequest. Note that the getPublicKey method is already implemented.

- public BankPublicKey getPublicKey()
  - This method is provided.
  - Generate a (BankPublicKey, BankSecretKey) key pair.
    - Note that the Encrypted<T> object encrypted with a BankPublicKey object can only be decrypted with the paired BankSecretKey object.
  - Store the BankSecretKey object to the member attribute secretkey and return the BankPublicKey object.
- public void fetchSymKey (Encrypted<BankSymmetricKey> encryptedkey, String AppId)
  - This method performs Step 3 of the handshake protocol, i.e., decrypting an encrypted BankSymmetricKey with the BankSecretKey object to retrieve it.
  - Decrypt the encryptedkey with the secretkey, and store the decrypted BankSymmetricKey object. Note that the BankSymmetricKey object should be stored together with the AppId, so that the correct keys can be found for different mobile applications.
    - Assume that the maximum number of handshakes is 10,000. You don't have to consider processing more than 10,000 handshakes such as exception handling for the 10,001st handshake.
    - If fetchSymKey is called multiple times for the same AppId, the old BankSymmetricKey object should be replaced with the new one.
  - If the encryptedkey is null, or decryption fails with the BankSecretKey, do not store anything.

- `public Encrypted<Boolean> processRequest(Encrypted<Message> messageEnc, String Appld)`
  - This method processes the encrypted request from the `MobileApp` and returns the encrypted response.
  - Find the `BankSymmetricKey` object corresponding to the `Appld`.
    - If the `BankSymmetricKey` does not exist for a given `Appld`, return null.
  - Decrypt the `messageEnc` with the `BankSymmetricKey` object.
    - If the `messageEnc` is null or decryption fails with the `BankSymmetricKey`, return null.
  - Retrieve the request information from the decrypted `Message` object and call the appropriate `Bank` methods. The final evaluation only considers message objects with "deposit", "withdraw" and "compensate"(Q 1.3)(all case sensitive) requests.
  - Fetch the boolean result of the invoked method, encrypt it with the `BankSymmetricKey` object and return it.

### Question 1.3: Hacking Detection [2 Marks]

**Objectives:** Implement four methods (`createAccount`, `compensate`, `secondaryAuthenticate`, `requestCompensate`)

**Descriptions:** Someone found that his/her account had been hacked, and part of his/her balance was withdrawn. He/She calls the bank for compensation. So with the transaction IDs he/she told, the bank compensates for the unintended withdrawal to his/her account. But of course, the bank checks whether he/she is the right owner of the account by a question that he/she optionally answered when he/she made his account.

#### Bank Class Specifications

- `public void createAccount(String id, String password, int initBalance, String question, String answer)`
  - This overloaded method creates a secure `bankAccount` with input parameters.
  - For simplicity, only two questions are allowed for authentication. Answer consists of alphabets only.
    - Q1. "BestProfessor" A. "JWLee", etc.
    - Q2. "BestTA" A. "KSS", "JWS", etc.
    - Note there is no space in `question` or `answer` string. Also those are case sensitive.(e.g. Wrong question or answer: "BestTa", "BestProfessor", "wonsukjiang")
  - If an account with a given id is already created and succeeds authentication with

input password, ignore initBalance and just add or update the question and answer attribute of the account. Account can have at most one pair of question and answer.

- Do nothing for illegal(not described above) question or answer.
- Do nothing for other cases. (Just finish this method)
- public boolean compensate (String id, String password, String questionAnswer, int[] transIdList)
  - If secondary authentication with questionAnswer is successful, check transaction log from Event class and sum robbed balance by matching transID array customer sent. Then deposit the robbed balance to the account, and return true.
    - If the transId in transIdList does not match the account's event or event is not a WithdrawEvent, just ignore that transId.
  - If authentication is not successful, return false.

#### BankAccount Class Specifications

- boolean secondaryAuthenticate(String questionAnswer)
  - Slice questionAnswer string into two(question, answer) pieces. They are separated by “,” and there is no space in the string.
  - If the question and answer provided by the customer match those stored in the account, return true. Else, return false.
  - If the account has never been set to the question and answer, return false.

#### MobileApp Class Specifications

- public Encrypted<Message> requestCompensate (String question, String answer, int[] transIdList)
  - Assume customers can check the transID of their transaction through mobileApp.
  - Send an encrypted transID array to the bank.
  - This method constructs an encrypted message to compensate for the money. The encrypted message is used by the processRequest method of the Bank class.
  - You should create a Message object with String “compensate”(case sensitive) , id, password, the concatenated string of question and answer with “,”(“question,answer”) and transIdList which has transIds of transactions he/she wants to get compensation for.
  - Then, you need to encrypt the Message object with the BankSymmetricKey object (generated from the sendSymKey), and return the Encrypted<Message>.

## Question 2: Relay race [4 Marks]

**Objective:** In this problem, we will simulate a simple relay race with humans and animals.

**Description:** Humans(runner, swimmer) and animals(rabbit, turtle) do the relay race. Each player class can be constructed at most two. There is one water region and the rest is a land region. Some players can't swim so they need to pass the baton to a swimmable player before the start point of the water region. If they arrive at the water region without passing the baton, they throw up(=give up) the race. Even if one team gives up the race, the other team keeps the race. Meanwhile, the simulator checks the race and notices players of their current situation. Humans boost their speed if distance between them and animals is less than specified value. If both teams throw up the game or one team reaches the goal, the game ends with a finish log.

### Question 2-1: Map, Eyesight and Message [1 Mark]

**Objectives:** Implement Map, Eyesight and Message class.

**Descriptions:** Players move on the Map defined. Players can see which is in their Eyesight. Messages are announced by a simulator and humans can hear it.

#### Map Class Specifications

- `public Map(double waterStart, double waterEnd, double mapEnd)`
  - The Starting point of the map is zero. So the size of the map is equal to `mapEnd`. `mapEnd` is in the range of  $0 < \text{mapEnd} \leq 100$ . We will not test with  $100+ \text{ of } \text{mapEnd}$  so just ignore that case. There is only one water region on the map, from `waterStart` to `waterEnd`. Water region can start from zero, and can end at `mapEnd`. Size of the water region should be a non-zero positive value. You don't have to handle the zero-water region case.
- `public boolean getOnWater(double position)`
  - If the player is in the water region, return true. The start point of the water region should be included and the end point should be excluded, that means, the player is considered as the player is on the water region when the player's position is 20 for water region 20~30.(Water region : [20,30))

#### Eyesight Class Specifications

Each player has their own Eyesight. Eyesight checks the distance to the next player or the region boundary. Eyesight's visible range is 3. `nextPlayerPosition` is the position of the next player who will be passed the baton by this Eyesight's owner.

- `public Eyesight(Map map)`
  - Constructor of this class with the Map the race proceeds.
- `public void setNextPlayerPosition(double position)`

- set nextPlayerPosition of Eyesight class.
- public double getDistanceToBoundary(double playerPosition)
  - playerPosition is the position of the player who has this Eyesight.
  - If the player is in the water region, return the distance to the water region endpoint.
  - If the player is on the land region preceding the water region, return the distance to the water region start point.
  - If the player is on the land region next to the water region, return the distance to the final line.
  - For all cases, if the calculated distance is larger than the range, return the range value, 3.
- public double getDistanceToNextPlayer(double playerPosition)
  - playerPosition is the position of the player who has this Eyesight.
  - If the distance to the next player is less than the range, return that distance. Else, return the range value, 3.

### Message Class Specifications

Message is a deliverable object from simulator to humans. It has four basic member attributes.

- private Player currentHuman : Current human team player who runs or swims
- private Player currentAnimal : Current animal team player which runs or swims
- private Map map : The map that the race is in progress.
- private int time : Time step when this message is created.

Now implement the next few methods.

- public Message(Player human, Player animal, Map map, int time)
  - Constructor of this class. **Remember, Messages cannot be changed after construction. Spoken words can't be taken back or modified.**
- public double getDistance()
  - Calculate the distance between currentHuman and currentAnimal. Return value should be non-negative value.
- public String toString()
  - Overriding method of toString method. There are six cases of message, so implement **accurately** as follows. We will evaluate your submitted code by printed output texts. Please check the exact format including space, comma, parentheses, square brackets etc. **No partial score will be given for tiny mistakes.** String inside the parentheses in the format is variable. Bolden red colored **s** in the format indicates space(just one space(" ")). Not including tab or several spaces like " ". Use each player(Runner, Swimmer, Rabbit, Turtle)'s toCustomString method(Note that toString method of Player class invokes this method) for *human/animal's description*.(Refer to the problem 2.2 description)
    - If both teams are in the middle of the race without both teams giving up. This case includes the case that one team gives up and one team is still running.
      - Format : "(time):**s**[RUNNING]**s**Human**s**teams**s**:**s**(currentHuman)'s



*description***s**is**s**at**s**(*currentHuman*)'s  
*position***s**/**s***Animal***s**team**s**:**s**(*currentAnimal*)'s  
*description***s**is**s**at**s**(*currentAnimal*)'s *position*"

- Example : "16: [RUNNING] Human team : 2nd human player, runner is at 58.0 / Animal team : 4th animal player, turtle is at 43.0"
- If *currentHuman* and *currentAnimal* are at the starting position
  - Format : "(time):**s**[READY]**s**Human**s**team**s**:**s**(*currentHuman*)'s  
*description***s**/**s***Animal***s**team**s**:**s**(*currentAnimal*)'s  
*description***s**are**s**at**s**0"
  - Example : 0: [READY] Human team : 1st human player, swimmer /  
 Animal team : 1st animal player, rabbit are at 0
- If *currentHuman* reaches at the end point earlier than animal team
  - Format : "(time):**s**[FINISH]**s**Human**s**team**s**sw**s**"
- If *currentAnimal* reaches at the end point earlier than human team
  - Format : "(time):**s**[FINISH]**s**Animal**s**team**s**sw**s**"
- If *currentHuman* and *currentAnimal* reach the end point at the same time.
  - Format: "(time):**s**[FINISH]**s**Both**s**team**s**sreach**s**the**s**goal**s**at**s**the**s**sa  
 me**s**time"
- If both teams throw up the race
  - Format : "(time):**s**[FINISH]**s**Both**s**team**s**sthrow**s**up**s**the**s**race"

## Question 2-2: Various Players [1.5 Marks]

**Objectives:** Implement *Player* class with abstract classes, subclasses and interfaces.

**Descriptions:** There are *Human* and *Animal* players and you should implement 4 classes(*Runner*, *Swimmer*, *Rabbit*, *Turtle*). Each of them has methods of their way of moving(*move()*, *swim()*) and they have a *Swimmable*(*Turtle*, *Swimmer*) interface or *Throwable*(*Rabbit*, *Runner*) interface. Plus, they have their own speed and it could be changed as their environment and racing condition.

Read the skeleton code and complete implementation of the following 7 classes. Some methods are already implemented and don't modify them.

### Interface Class Specifications

There are two interface classes. *Swimmable* is for *Swimmer* and *Turtle*, and *Throwable* is for *Runner* and *Rabbit*. These classes are already implemented.

- public interface *Swimmable*
  - *Swimmable* players can swim at the water region. It invokes a *swim* method. You should implement the *swim* method with proper details for *Swimmable* players.
- public interface *Throwable*
  - Non-swimmable players throw up the race when they cannot pass the baton to the swimmable player until they reach the starting point of the water region. You

should implement the `throwUp` method with proper details for `Throwable` players.

## Player Class Specifications

`Player` class is a parent class of `Human` and `Animal` class. Below are member attributes of this class. Note that the `Player` class has a `Comparable` interface.

- double `position`, `velocity` : player's position and velocity
- double `nextPlayerPosition` : Position of the next player. If this player is the last player, `nextPlayerPosition` is the map endpoint position.
- boolean `currentPlayer` : True when this player is moving with the baton. Zero value means this player is waiting for the baton or finished his race after passing over the baton.
- `Eyesight` `eyesight` : Player's `Eyesight` class object.
- int `playerNum` : `playerNum` indicates the player number in the team.(ex. 3rd player in the human team : `playerNum` is 3)
- String `playerType` : It indicates that this player is "Animal" or "Human". We don't consider any other type or typo case in tests like "human" or "Animan". Note this is final attribute.

Now implement the following few methods.

- public `Player(double velocity, Map map, String playerType)`
- public `Player(double position, double velocity, double nextPlayerPosition, Map map, String playerType)`
  - Constructors are already provided. If `position` value is not specified, `position` is set to zero for default.
- public void `setPosition(double position)`
  - Set the Player's position.
- public void `setPlayerNum(int num)`
  - Set the Player's number in the team.
- public void `setNextPlayerPosition(double position)`
  - Set the next player's position who will be passed the baton by this player in `Player` class and Player's `Eyesight`
  - This provided method is called by the `Simulator` class before the start of the race because the `Simulator` manages the sequence of the players.
- abstract public void `move()`
  - Player can move for its velocity from the current position. Note that this is an abstract method.
- abstract public boolean `getThrowUp()`
  - If a player throws up the race, return 1. Else, return 0. Note that this is an abstract method.
- abstract public void `hear(Message message)`
  - Humans can hear the message and they boost their speed in a specific case. Note that this is an abstract method.
- public void `passBaton(Player nextPlayer)`
  - Set `currentPlayer` attribute to false and `nextPlayer`'s `currentPlayer` attribute to true.
  - This method will be invoked in `Simulator` class.

- `protected double getMovableDistance(double velocity)`
  - Return movable distance at this time step. Basically, the player can move for velocity, but you should consider two cases of limitation.
    - Movable distance can be less than velocity if distance to next player is shorter than value of velocity.
    - Movable distance can be less than velocity if distance to the next region(land to water, water to land, land to finish line) is shorter than the value of velocity.
  - To check these limitations, use methods of `Eyesight` class.

#### Human Class Specifications

- `Human` class is the parent class of `Runner` and `Swimmer` class. This abstract class is already provided.

#### Animal Class Specifications

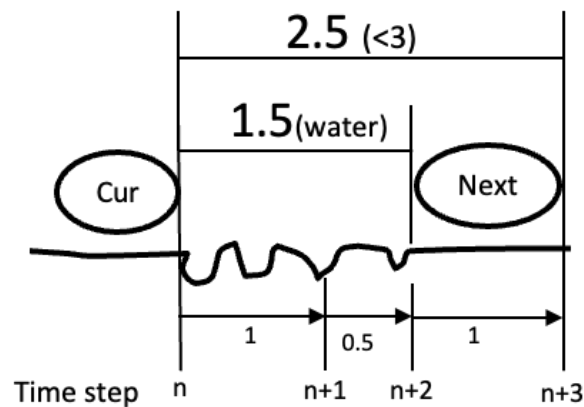
- `Animal` class is the parent class of `Rabbit` and `Turtle` class. Animals can't understand the words, so `hear` method is empty. This abstract class is already provided.

#### Runner Class Specifications

- `public Runner(Map map)`
- `public Runner(double position, Map map)`
  - Set `Runner`'s position and velocity and the map `Runner` runs on. `Runner`'s default velocity is 2. If position is not specified, set position value to zero.
- `public void hear(Message message)`
  - If the distance to the current animal player is less than 2 (i.e.,  $|Runner's\ position - Animal's\ position| < 2$ ) and the `Runner` can see(e.g., in his/her eyesight range) the end line(`mapEnd`) or next player, he/she boosts his/her velocity to 2.5 until he/she hears the next message.
- `public void move()`
  - `Runner` moves to the goal with velocity per time step. If the `Runner` cannot move further because of water, he/she stops at the boundary of water and throws up the game. Then, wait for the animal team until they reach the goal or give up the race. But there is one exception. If the next player or end line(`mapEnd`) is in the sight range of `Runner`, `Runner` doesn't give up and is carried along by the wave to the next player or end line(`mapEnd`) with very low speed, 1. Also, if distance to the boundary of water/land region is less than velocity, `Runner` just moves to the boundary at that time step. **Note** : `Runner` can't swim (just moved by the wave), so you don't need to implement a `swim` method, just set the velocity to 1 for this movement. Also, since `Runner` is not swimming (just floating) in the water, so

Runner can hear the Message on the water region.

■ Example for your understanding



- Runner can see the next player, so drifts away with velocity 1.
- Runner moves just for 0.5(<1) because he/she reaches the boundary.
- Runner's velocity is reverted to 2(or 2.5) on the land region, but moves just for 1 because he/she reaches the next player.
- If distance to the next player is less than velocity, the Runner moves to the next player's position. Note : You already implemented a related method in Player class.
- `public String toCustomString()`
  - Follow this format and return. Be cautious of small mistakes like st,nd,th.
    - Format : "Athshumansplayer,srunner"
    - Example : "1st human player, runner" (O) "1st human player, runner"(X)
- `public boolean throwUp(double position, Map map)`
  - Runner throws up the game when he/she reaches the start point of the water region. But as mentioned above, if Runner can see the next player or end line(`mapEnd`), he/she will not throw up and try to overcome the water barrier.
  - If Runner's starting position is on the water, Runner throws up the game if he/she receives the baton. Of course one exception of not giving up the game can be applied to this case.
- `public boolean getThrowUp()`
  - Return the result of the `throwUp` method.

## Swimmer Class Specifications

Swimmer can't hear while swimming. Swimmer can run and swim but speed in those cases are different.

- `public Swimmer(Map map)`
- `public Swimmer(double position, Map map)`
  - Set Swimmer's position and velocity and the map he/she runs or swims on. Swimmer's default running velocity is 1.5 and default swimming speed is 2. If position is not specified, set position value to zero.
- `public void hear(Message message)`
  - If the Swimmer is on the land region and the distance to the current animal player is less than 2 (i.e.,  $|Runner's\ position - Animal's\ position| < 2$ ) and if he/she can see the end line (mapEnd) or next player, he/she boosts his/her running speed to 2 until he/she hears the next message.
- `public void move()`
  - Swimmer moves to the goal with velocity per time step on the land and swims for swimSpeed on the water. But if Swimmer starts a race on the land region, Swimmer needs one time step to warm up at the water region start point before entering the water region. Swimmer doesn't give up the race in any situation. If distance to the next player is less than velocity for land region and swimSpeed for water region, the Swimmer moves to the next player's position. Also, if distance to the boundary of water/land region is less than swimSpeed/velocity, Swimmer just moves to the boundary at that time step. Implement and use the swim method.
  - Of course you could implement this method which makes a desirable result of the whole operation without the swim method, but for practicing the interface concept, implement the swim method as follows and use it here. There are test cases for each method (e.g., only test Swimmer.swim()) so we strongly recommend to follow each method description.
- `public void swim()`
  - If Swimmer needs to warm up, he/she doesn't move and stays in his/her position.
  - If distance to the next player is less than swimSpeed, the Swimmer moves to the next player's position.
- `public boolean getThrowUp()`
  - Just return false. Swimmer never gives up.
- `public String toCustomString()`

- Follow this format and return.
  - Format : “Athshumanplayer,sswimmer”
  - Example : “2nd human player, swimmer”(O) “2th human player, swimmer”(X)

#### Rabbit Class Specifications

- public Rabbit(Map map)
- public Rabbit(double position, Map map)
  - Set Rabbit's position and velocity and map it runs on. Rabbit's default velocity is 3. If position is not specified, set position value to zero.
- public void move()
  - Rabbit moves to the goal with velocity per time step. If the Rabbit cannot move further because of water, it stops at the boundary of water and throws up the game. Then, it waits for the human team until they reach the goal or give up the race. If distance to the next player is less than velocity, the Rabbit moves to the next player's position. Note : You already implemented a related method in Player class.
- public String toCustomString()
  - Follow this format and return.
    - Format : “Athsanimalplayer,srabbit”
    - Example : “1st animal player, rabbit”
- public boolean throwUp(double position, Map map)
  - If the Rabbit is on the point that it cannot move ahead due to the water, return true. Else, return false. If Rabbit's starting position is on the water, Rabbit throws up the game if it receives the baton.
- public boolean getThrowUp()
  - Return the result of the throwUp method.

#### Turtle Class Specifications

- public Turtle(Map map)
- public Turtle(double position, Map map)
  - Set Turtle's position and velocity and the map it runs or swims on. Turtle's default running velocity is 1 and default swimming speed is 2.5. If position is not specified, set position value to zero.
- public void move()
  - Turtle moves to the goal with velocity per time step on the land and swims for swimSpeed on the water. It doesn't give up the race in any situation. If distance

to the next player is less than `velocity` for land region and `swimSpeed` for water region, the turtle moves to the next player's position. Use the `swim` method. Also, if distance to the boundary of water/land region is less than `swimSpeed/velocity`, `Turtle` just moves to the boundary at that time step

- Of course you could implement this method which makes a desirable result of the whole operation without the `swim` method, but for practicing the interface concept, implement the `swim` method as follows and use it here.
- `public void swim()`
  - If distance to the next player is less than `swimSpeed`, the `Turtle` moves to the next player's position.
- `public boolean getThrowUp()`
  - Just return false. `Turtle` never gives up.
- `public String toCustomString()`
  - Follow this format and return.
    - Format : "Ath`s`animal`s`player,`s`turtle"
    - Example : "3rd animal player, turtle"

## Question 2-3: Simulator [1.5 Marks]

**Objectives** : Implement `Simulator` class.

**Description** : `Simulator` lets the race proceed and pass the baton. Also, the `Simulator` snapshots the current racing situation for every time step and announces it to all. Evaluation of this sub problem includes checking various conditions of race simulation output. So if your code of Problem 2.1 and 2.2 is wrong, you could not get a full score for Problem 2.3 even though you implement a perfect `Simulator` class.

**Note**: You'll face a new Java Collection class called '`ArrayList`' in the skeleton code of this problem. `ArrayList` is a variable length Collection that works like an Array. You can use `E get(int index)`, `E set(int index, E element)` and `int size()` to use the same functionality of Array like `[]` and `int length()`. Additional information is available in [ArrayList\(Java SE 11 & JDK 11\)](#). Again, do not use this class in any other class except for `Simulator`.

### Simulator Class Specifications

Note that `maxTeamPlayerNum` is 4. Each kind of player can be constructed at most 2. **You don't have to consider more than three players of one category case such as three Rabbits in one team.** `Simulator` has two `ArrayList` for managing each team's players. `currentHuman` is moving human player who has baton and `currentAnimal` is moving animal player which has baton. `raceLogForEval` stores the race log and it will be used to score this problem.

- `public Simulator(ArrayList<Player> humanPlayers, ArrayList<Player> animalPlayers, Map map)`
  - Update `map`, `currentHuman`, `currentAnimal` attributes of this class.
  - Each `ArrayList` of human and animal are constructed outside of the `Simulator` class. But the `Simulator` sorts those arrays in ascending order of starting position of `human/animalPlayers`. Then the `Simulator` allocates `Human/AnimalPlayerNum` and `NextPlayerPosition` for each player. You don't have to consider the case that several team players have equal starting positions. We will test with unique starting positioned players in one team. Of course different team players can have the same starting position.
  - Also, we will not consider the case that the start position of any player is equal to the map end position. (No player on the map end point at time 0)
  - Note that `Player` class implements a `Comparable` interface.
  - Since we have not studied 'exception handling' yet, so no need to take care of null `ArrayList` input cases.
- `public void snapshot()`
  - Update `currentHuman` and `currentAnimal` attributes if changed.
  - If one player reaches the next player's position, invoke `passBaton` method of `Player` class.
- `public Message talk(int time)`
  - Check the racing situation and create a `Message` to announce it to the players.
  - `Simulator` also notices race start and race finish.
  - This method is invoked for every time step from zero to race finish.
  - This method is already implemented.
- `public boolean getRaceFinish()`
  - Return `raceFinish` flag to notice the testbench that race ends.
- `public void simulate()`
  - From time step 0, the `Simulator` makes the `currentAnimal` and `currentHuman` move, and update `currentHuman` and `currentAnimal` attributes if needed for every time step until one of the teams finishes the race or both teams throw up the race. `Messages` should be created by `talk` method from time step 0 to race finish time(0 and finish time included), which means `[READY]` and `[FINISH]` `Messages` should be created once. `Human` players' `hear` method is invoked for every time step from 0 except for the last message which notices race finish. Time step increases by one after both teams' players finish their move or stay(throw up case) for that time step. Set the `raceFinish` flag to `true` when the race finishes.
  - If the number of players of team exceeds `maxTeamPlayerNum` or `Animal/Human`



player is mis-allocated in Human/Animal team or no Player of any team exists at position 0 at time 0, then don't go ahead the simulation(just finish the simulate method) and just store "[ERROR]sTeam sbuilding serror" to raceLogForEval[0] and set the raceFinish flag to true.