

Homework Assignment 1

Cybersecurity

COSC 3371 / 2022 Spring

In this homework assignment, you can use either the Java `javax.crypto` or the Python `Crypto.Cipher` package. To get familiar with the Java package, see the reference at <https://docs.oracle.com/javase/8/docs/technotes/guides/security/crypto/CryptoSpec.html#Cipher>. To get familiar with the Python package, see the reference at <https://pycryptodome.readthedocs.io/en/latest/src/cipher/cipher.html>.

Please solve the following problems by completing the attached Java or Python source file. For each problem, replace the code between `// BEGIN SOLUTION` and `// END SOLUTION` (or between `# BEGIN SOLUTION` and `# END SOLUTION`) with your solution (you can also import any standard Java or Python package). The submission uploaded to Blackboard should include the completed Java or Python source file. Please make sure that the uploaded source file can be compiled and executed without any unhandled exceptions and that you have not used any non-standard libraries.

In each problem, your goal is to recover a plaintext (or at least some information about its contents). Please note that you will need a working Internet connection to solve this assignment. Each problem builds on the preceding one, so you have to solve them in order.

Problem 1 (2 points): The Game is Afoot

You are at 221B Baker Street in the company of Dr. Watson, when the following e-mail arrives:

"Dear Mr. Sherlock Holmes,

I must once again ask you to help us as a consulting detective. Three days ago, the invaluable Koh-i-Noor diamond was stolen from the Tower of London. We fear that the thieves are planning to sell the diamond on the black market, where it may be lost forever. Fortunately, the thieves acted hastily and they accidentally left a disk drive at the scene of the crime. We recovered two files from this drive (please find them attached), but our detectives at Scotland Yard were not able to make sense of them. We believe that the infamous Professor Moriarty is behind this spiteful act, but our detectives have no leads to follow. Sherlock, you are our only hope!

*Sincerely,
Inspector Lestrade"*

The two files (`cipher1.bin` and `msg1.txt`) are attached to the homework assignment. See the solution template for help.

Problem 2 (1.5 points): The Jigsaw Puzzle

You look at Dr. Watson... he has fallen asleep while you were busy decrypting the message. You suspect that he would not be much help anyway, so you decide not to wake him up. Instead, you look at the ciphertext and see that it is 48 bytes (384 bits) long, which means that it consists of only three AES blocks, each being 16 bytes (128 bits) long. You can just try to rearrange the three blocks in different ways (there are only 5 possibilities) to restore the ciphertext.

Problem 3 (1.5 points): Shaken, Not Stirred

Dr. Watson wakes up, looks at the ciphertext, and scratches his head. Not a good sign, obviously. It appears that you are on your own again. You look at the ciphertext: it is a bitmap image (BMP file) that has been encrypted using ECB block-cipher mode, so you should be able to see the patterns of the plaintext. However, you cannot open the image since the header of the file is encrypted, so no image-viewer program will be able to figure out how to display it (e.g., without the header, a program will not know what the width and height of the image are). Suddenly, you get an idea: what if the encrypted image has the same format as the plain one? You could restore the header by copying the first few thousand bytes of the plain image (`msg3.bmp`) to overwrite the first few thousand bytes of the third ciphertext (`cipher3.bmp`), and then open the modified ciphertext in an image viewer!

Problem 4 (2 points): Same but Different

It seems that your luck has run out: the cunning Professor Moriarty used a secure cipher, a secure mode of operation, and a secure key. Dr. Watson is about to call Inspector Lestrade to tell him that you cannot discover the location of the meeting, when you suddenly realize that Moriarty made a crucial mistake: he used the same key twice with CTR block-cipher mode, which is essentially a stream cipher. Since you have one of the plaintexts (`plain4A.txt`) and both ciphertexts (`cipher4A.bin` and `cipher4B.bin`) were XORed to the same pseudorandom sequence, you should be able to easily recover the other plaintext!¹

Problem 5 (2 points): Checkmate

Dr. Watson looks puzzled. How could he decrypt the ciphertext without knowing the mysterious Professor Moriarty's birthdate? To be fair, you do not have a clue about those three numbers either. However, there are not that many possible combinations, so you could try to brute-force the key. But how will you know which key is the correct one? Well, the plaintext is probably a simple text file containing English text encoded in UTF-8 (or in ASCII). This means that the value of every plaintext byte should be between 0 and 128, which enables you to recognize a correctly decrypted plaintext.

¹ The bitwise XOR operation can be performed in both Java and Python using the `^` operator (e.g., `byte xor = (byte) (byte1 ^ byte2)`; in Java).