OTP Assignment: By Riley Mete

Questions:

1. What is OTP? What are the assumptions to achieve perfect secrecy?
    1. One-time-pad (OTP) is an encryption technique that guarantees perfect secrecy. This means that if OTP is applied correctly, then the encryption cannot be hacked. To achieve this perfect secrecy, one must ensure that a file is encrypted with a single-use key. This means that the key cannot be reused for any other encryption. In addition to a single-use key, the key must be the same length of the plaintext and each byte of the key must be generated randomly.
2. From the results of Task3, what do you observe? Are you able to derive any useful information from either of the encrypted images? What are the causes for what you observe?
    1. Based on my results from Task3, I was able to observe that each encrypted image is completely random and that there is no information that can be gathered from the encrypted image itself. The encrypted image looks like static and there is no way to depict what the plaintext image was by looking at the encrypted image. I believe the reason for this completely random encrypted image is since the key used to encrypt the image is composed of completely random characters and by xor-ing the image to this key, each byte in the image is now completely random as well. When I xor the encrypted image again with the same key, the original image can be obtained and viewed again.
3. From the results of Task4, are you able to derive any useful information about the original plaintexts from the resulting image? What are the causes for what you observe?
    1. Based on my results from Task 4, it appears that the resulting image is a combination of both original plaintext images. Though the images are now blended, one can still figure out what each original image was supposed to be. This is a prime example of why it is very important to use an OTP key for only one encryption. In this case, since each image was encrypted using the same key, then an attacker would be able to gain information about both plaintexts by simply xor-ing the encrypted images together.

Task 1:

```
import string
from Cryptodome.Random import get_random_bytes

def xor_strings(s1, s2):
    xor_list = [ord(a) ^ ord(b) for a,b in zip(s1,s2)]
    return "".join('{:02x}'.format(a) for a in xor_list)

def checkStringLengths(s1, s2):
    s1_length = len(s1)
    s2_length = len(s2)
    if s1_length != s2_length:
        return "Error: String lengths don't match.\n String one has length: " +
str(s1_length) + "\n String two has length: " + str(s2_length)
    else:
        return xor_strings(s1, s2)



def main():
    s1 = "Darlin dont you go"
    s2 = "and cut your hair!"

    s3 = "Darlin dont you go and"
    s4 = "cut your hair!"

    print ("Test with equal length strings\n\tString1: " + s1 + "\n\tString2: " + s2)
    print (checkStringLengths (s1, s2) + "\n\n")
    print ("Test with non equal length strings\n\tString1: " + s3 + "\n\tString2: " +
s4)
    print (checkStringLengths (s3, s4))

if __name__ == "__main__":
    main()
```

```
rileymete@Rileys-MacBook-Pro OTP % python3 task1.py
Test with equal length strings
        String1: Darlin dont you go
        String2: and cut your hair!
250f164c0a1b5444160101525907144 9154e


Test with non equal length strings
        String1: Darlin dont you go and
        String2: cut your hair!
Error: String lengths don't match.
 String one has length: 22
 String two has length: 14
```

Task 2:

```
from Cryptodome.Random import get random bytes
import sys
import base64
from Cryptodome.Util.Padding import pad, unpad



def xor bytes(a, b):
    c = bytearray()
    for idx in range(len(a)):
        c.append(a[idx] ^ b[idx])
    return c



def main(in file path):
    with open(in file path, mode='rb') as in file:
        file bytes = in file.read()

    print("THIS IS THE PLAINTEXT:")
    print(file bytes.decode('utf-8') + "-----------------------------------------\n")
__
    # Get a key of random bytes that is the length of plaintext
    key = get random bytes(len(file bytes))

    # Encrypt a file using OTP
    with open("encrypt.txt", "wb+") as encrypt:
        encrypt.write(xor bytes(file bytes, key))
        encrypt.seek(0)
        encrypt bytes = encrypt.read()

    print("THIS IS THE ENCRYPTED CIPHERTEXT (not decoded)")
    print(encrypt bytes)

    print("\nTHIS IS THE ENCRYPTED CIPHERTEXT (decoded)")
    print(base64.b64encode(encrypt bytes).decode('utf-8'))
    print("-----------------------------------------\n")

    # Write the decrypted cipher text to a file using the same random key
    # Decode the cipher text so it is in readable format
    with open("decrypt.txt", "w+") as decrypt:
        decrypt.write(xor bytes(encrypt bytes, key).decode('utf-8'))
        decrypt.seek(0)
        decrypt bytes = decrypt.read()

    print("THIS IS THE DECRYPTED CIPHERTEXT:")
    print(decrypt bytes + "-----------------------------------------\n")

if __name__ == "__main__":
    main(sys.argv[1])
```

As shown in the output from task2, one can both encrypt and decrypt a file using a one-time-pad. When the file is originally encrypted with the randomly generated key that is the same length of the plaintext file, the result is a completely random string of bytes. When the ciphertext is then xor-ed again with the same key, the result is the original plaintext. This is a basic example of how OTP works. If two users have access to the randomly generated key, they can encrypt a file and then decrypt the encrypted file by using the same key.

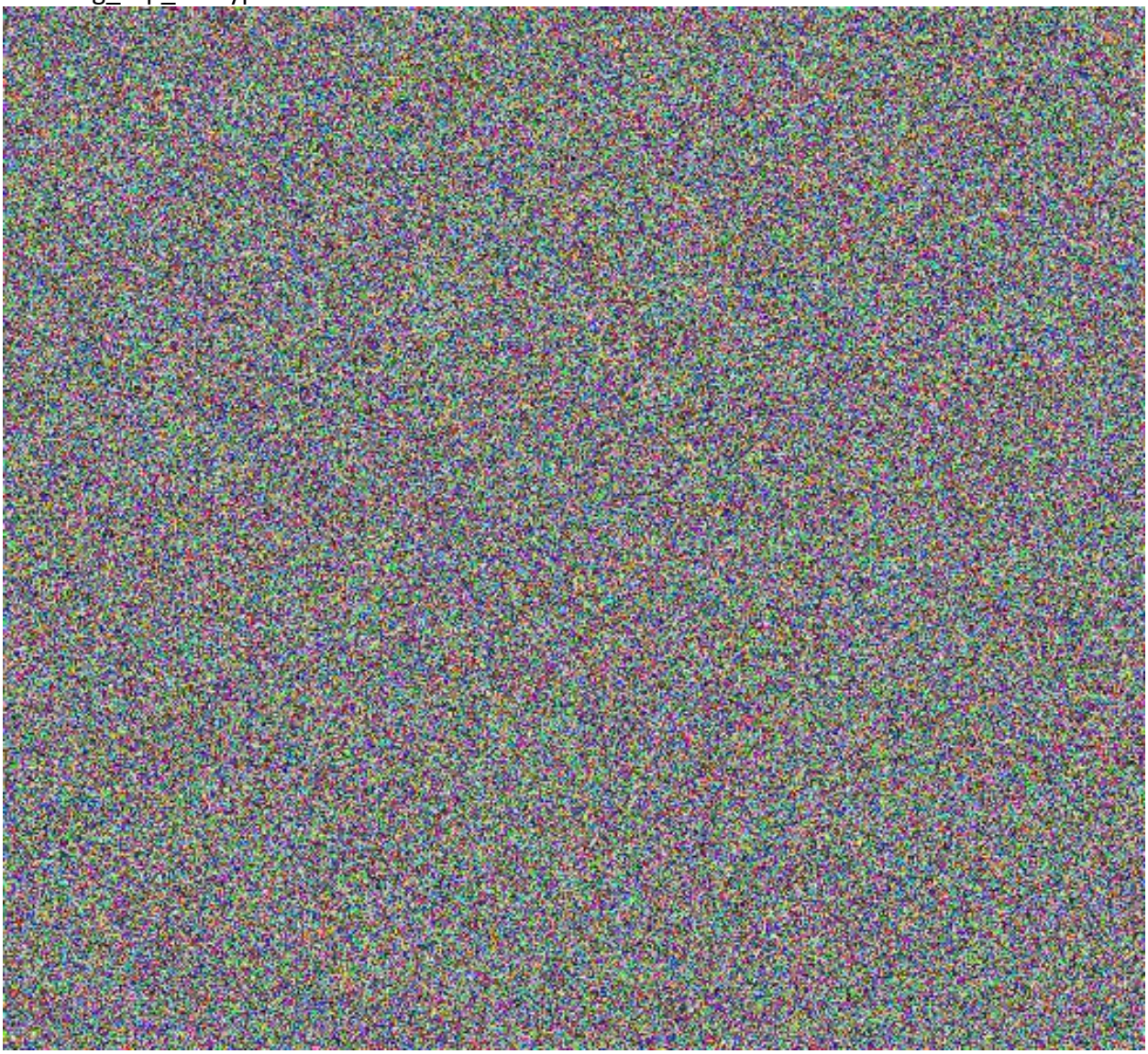
Task 3:

```
from Cryptodome.Random import get_random_bytes
import sys



def xor_bytes(a, b):
    c = bytearray()
    for idx in range(len(a)):
        c.append(a[idx] ^ b[idx])
    return c

def write_file(outfile, header, ciphertext):
    # Write to output file, for this we need the original bmp header
    # and the encrypted ciphertext
    with open(outfile, "wb") as output:
        output.write(header+ciphertext)



def main(in_file_path):
    with open(in_file_path, mode='rb') as plaintext:
        plaintext = plaintext.read()

    # Preserve header and get bytes for the image
    header = plaintext[:54]
    image = plaintext[54:]

    # Get a key of random bytes that is the length of plaintext
    key = get_random_bytes(len(image))

    ciphertext = xor_bytes(image, key)

    # Encrypt a BMP image using OTP
    encrypted_file = in_file_path.split(".")[0] + "_otp_encrypted.bmp"
    write_file(encrypted_file, header, ciphertext)

    # Decrypt a BMP image using the same key used in OTP encryption
    decrypted_ciphertext = xor_bytes(ciphertext, key)

    # Write the decrypted image to a bmp file
    decrypted_file = in_file_path.split(".")[0] + "_otp_decrypted.bmp"
    write_file(decrypted_file, header, decrypted_ciphertext)

if __name__ == "__main__":
    main(sys.argv[1])
```

cp-logo_otp_encrypted

cp-logo_otp_decrypted

mustang_otp_encrypted



mustang_otp_decrypted

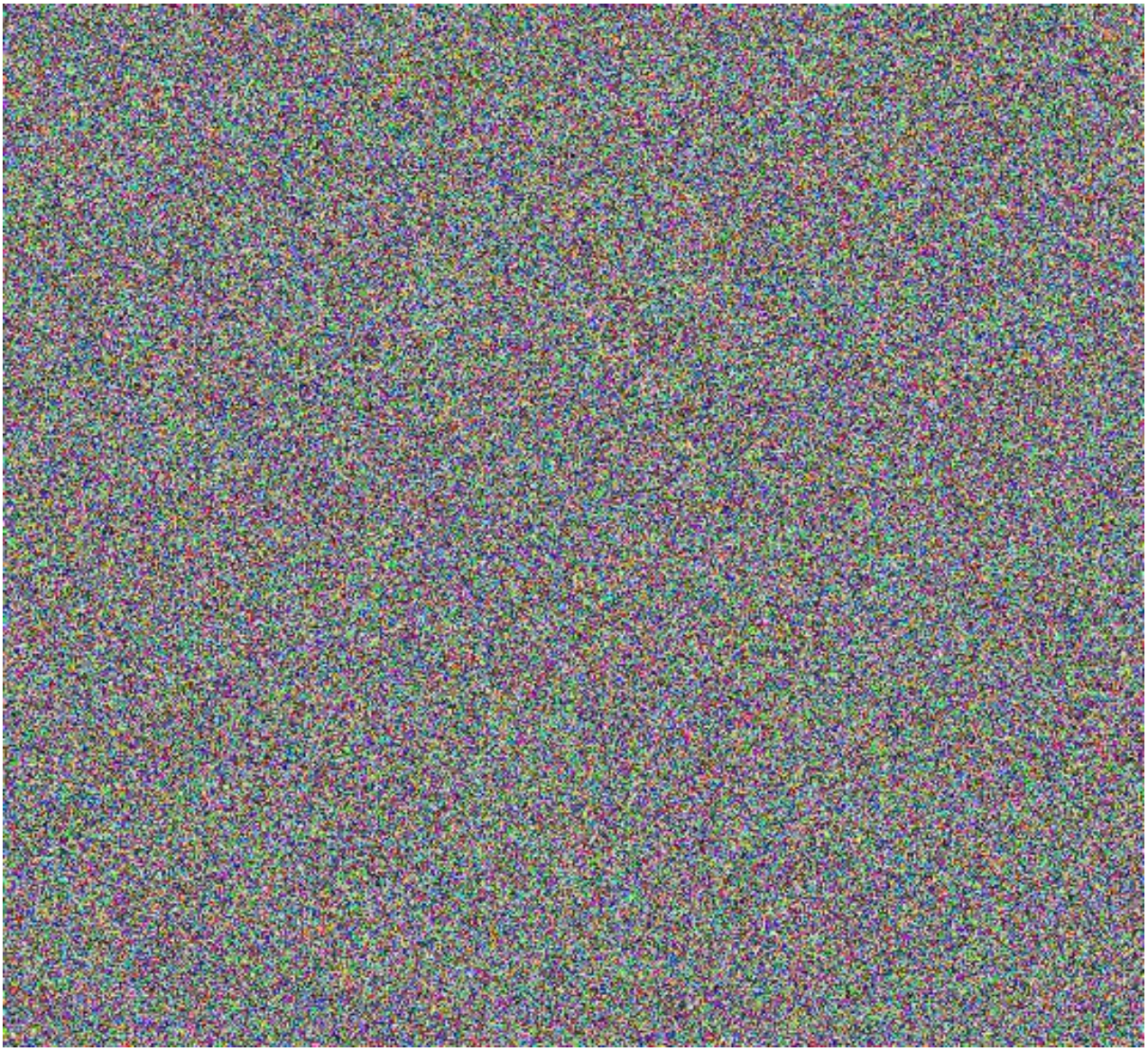
In task3, I observed that one can encrypt and decrypt an image using OTP. In the encrypted images, no useful information can be obtained to help decipher what the original plaintext image was supposed to be. As depicted in the encrypted images, they both look like TV static or a bunch of random noise. Note: to encrypt a BMP image, one must preserve the original header so that the image can be generate again during decryption. Regarding decryption, one is able to decrypt an OTP encrypted image by xor-ing the image with the same key used for encrypting and then appending the preserved header back to it.

Task 4:

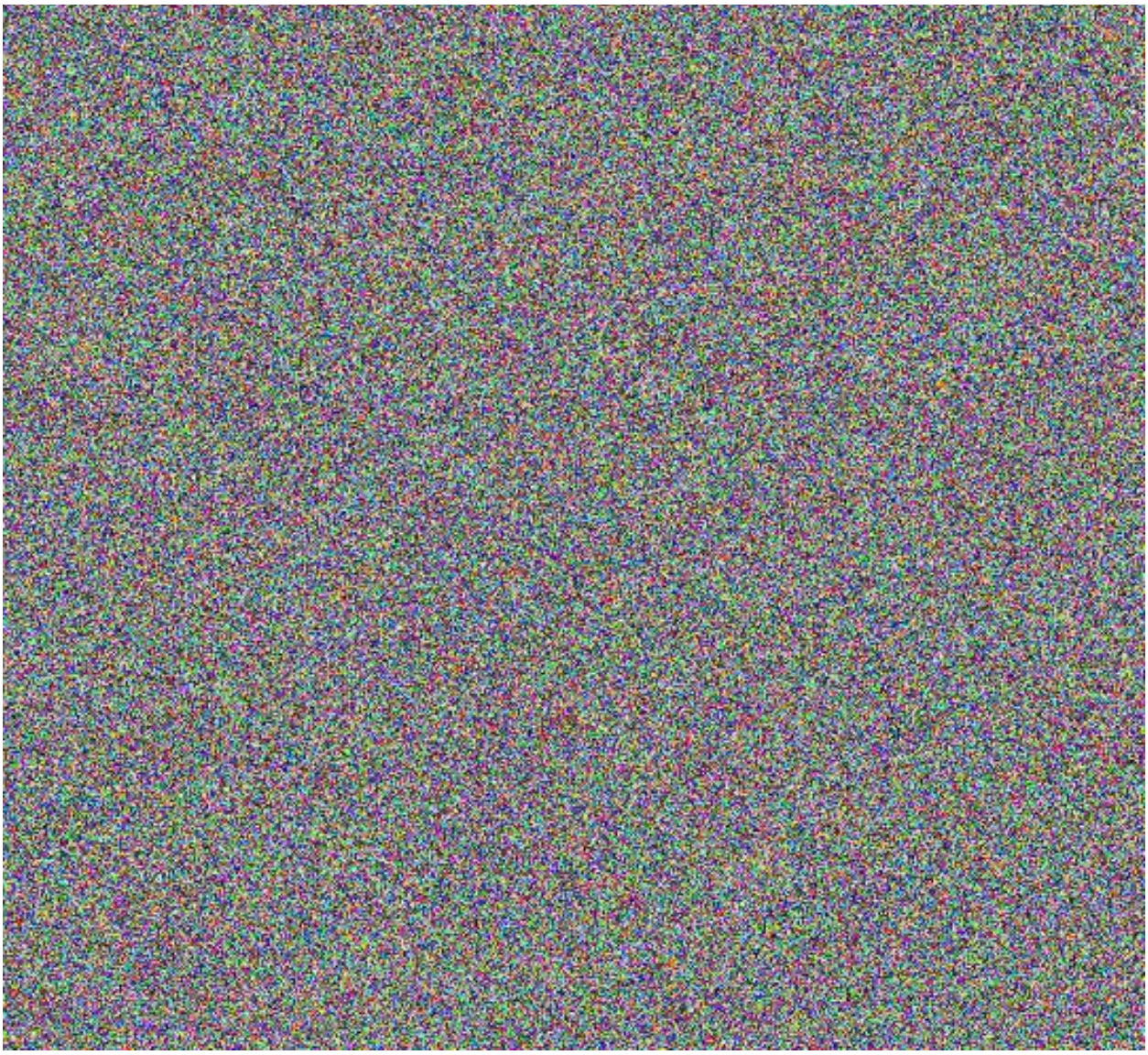
```
from Cryptodome.Random import get_random_bytes
from sys import *


def xor_bytes(a, b):
    c = bytearray()
    for idx in range(len(a)):
        c.append(a[idx] ^ b[idx])
    return c

def write_file(outfile, header, ciphertext):
    # Write to output file, for this we need the original bmp header
    # and the encrypted ciphertext
    with open(outfile, 'wb') as output:
        output.write(header+ciphertext)


def main():

    in_file_path1 = argv[1]
    in_file_path2 = argv[2]

    print(in_file_path2)
    with open(in_file_path1, mode='rb') as plaintext1:
        plaintext1 = plaintext1.read()


    with open(in_file_path2, mode='rb') as plaintext2:
        plaintext2 = plaintext2.read()

    # Preserve header and get bytes for the image
    header1 = plaintext1[:54]
    image1 = plaintext1[54:]
    header2 = plaintext2[:54]
    image2 = plaintext2[54:]

    # Get a key of random bytes that is the length of plaintext
```

```
    # This key will be used for both image encryptions
    key = get_random_bytes(len(image2))

    # Get the encrypted ciphertext for both images
    # Use the same key to encrypt both
    ciphertext1 = xor_bytes(image1, key)
    ciphertext2 = xor_bytes(image2, key)

    # XOR both encrypted images together
    decrypted_ciphertext = xor_bytes(ciphertext1, ciphertext2)

    # Write the encrypted images to a file
    encrypted_file1 = in_file_path1.split(".")[0] + "_two_time_pad_encrypted.bmp"
    write_file(encrypted_file1, header1, ciphertext1)
    encrypted_file2 = in_file_path2.split(".")[0] + "_two_time_pad_encrypted.bmp"
    write_file(encrypted_file2, header2, ciphertext2)

    # Write the decrypted image to a bmp file
    decrypted_file1 = in_file_path1.split(".")[0] + "_two_time_pad_decrypted.bmp"
    write_file(decrypted_file1, header1, decrypted_ciphertext)

    # Write the decrypted image to a bmp file
    decrypted_file2 = in_file_path2.split(".")[0] + "_two_time_pad_decrypted.bmp"
    write_file(decrypted_file2, header2, decrypted_ciphertext)

if __name__ == "__main__":
    main()
```

mustang_two_time_pad_encrypted



cp-logo_two_time_pad_encryption



cp-logo_two_time_encryption xor-ed with mustang_two_time_pad_encryption

In task 4, I observed why it is bad practice to use an OTP key for multiple encryptions. Even though mustang and cp-logo images can be encrypted in a way that appears as if they are perfectly random, when the two encrypted images are then xor-ed together the resulting image is a combination of both as shown above. Though the image is combined together, it is rather easy to determine which each image was originally.