III. TASKS

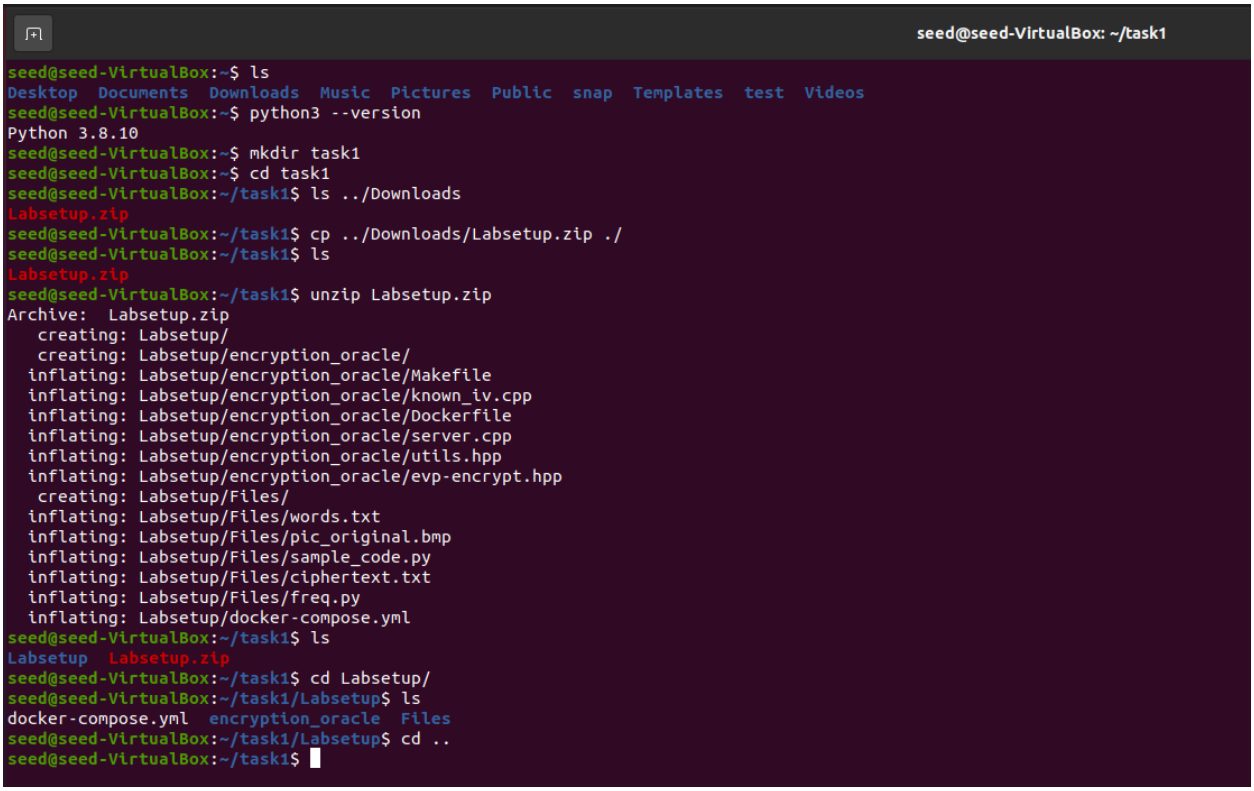
Task 1: Frequency Analysis:

1. Why is monoalphabetic substitution cipher not secure?

A monoalphabetic cypher is a substitution cypher in which the cypher throughout the encryption process for a given key, the plaintext is mapped to a certain character in the ciphertext. Take an example, if 'E' is encrypted as 'G,' then 'E' will always be encrypted to 'G.' Consequently, this is vulnerable to frequency attacks to analyze the encryption process in terms of fixed substitution.
Through statistical analysis of a language, it can know the frequently occurring letters or combinations of letters, especially 2 letter combinations and 3 letter combinations.
A crypto-analyst could analyze the ciphertext for frequently used letter combinations, guess the corresponding plain text letters, substitute the to construct a partial ciphertext message and continue working on guessing a few letters at a time. Observing, repeated guesses, and backtracking for incorrect guesses makes it easier to break the security of monoalphabetic substitution.

2. Provide and explain Task1 Screenshots

a. Downloaded the LabSetup folder from the SEED website. (https://seedsecuritylabs.org/Labs_20.04/Crypto/Crypto_Encryption/).



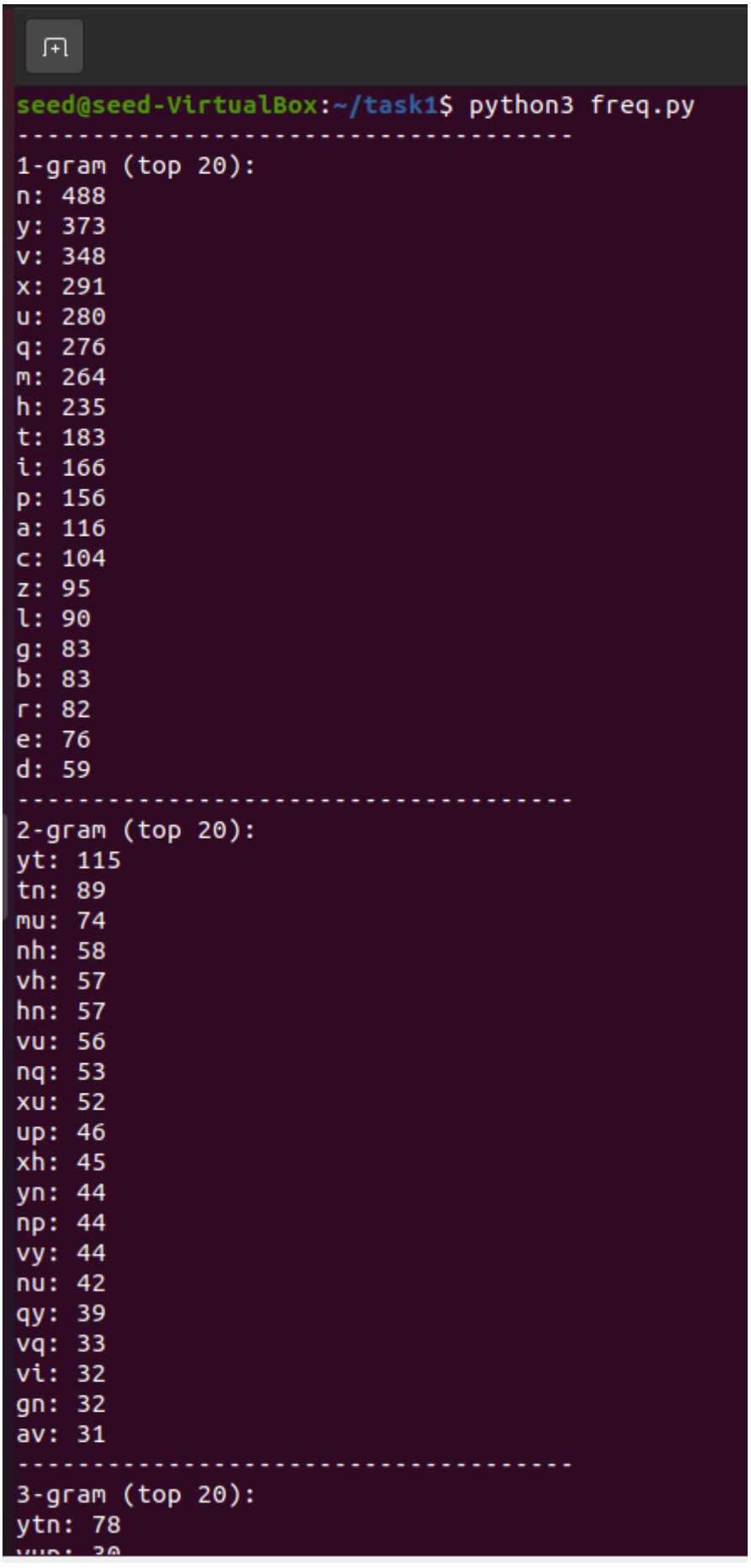
b. Obtained the ciphertext.txt file.

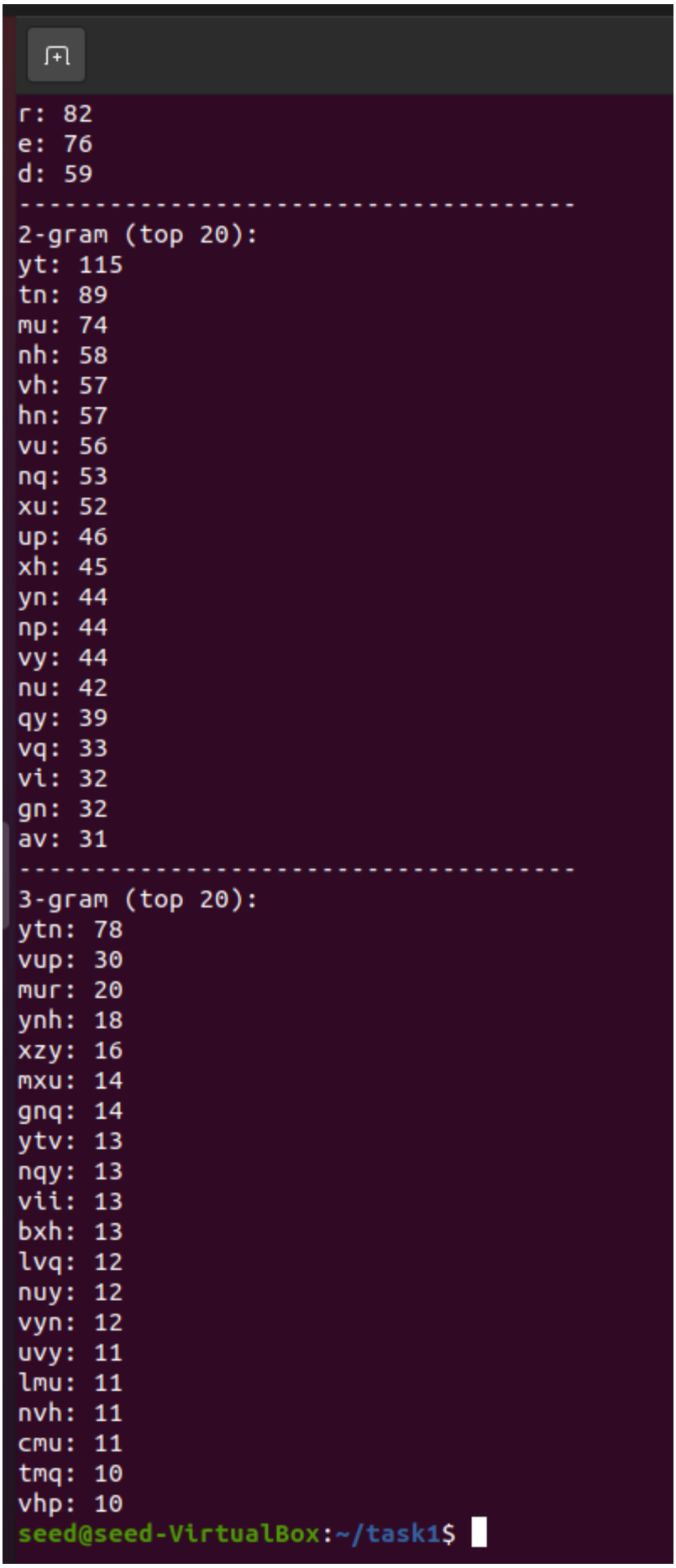
```
seed@seed-VirtualBox:~/task1$ ls
Labsetup  Labsetup.zip
seed@seed-VirtualBox:~/task1$ cp Labsetup/
docker-compose.yml  encryption_oracle/  Files/
seed@seed-VirtualBox:~/task1$ cp Labsetup/Files/
ciphertext.txt    freq.py          pic_original.bmp  sample_code.py    words.txt
seed@seed-VirtualBox:~/task1$ cp Labsetup/Files/ciphertext.txt ./
seed@seed-VirtualBox:~/task1$ ls
ciphertext.txt  Labsetup  Labsetup.zip
seed@seed-VirtualBox:~/task1$ cp Labsetup/Files/freq.py ./
seed@seed-VirtualBox:~/task1$ ls
ciphertext.txt  freq.py  Labsetup  Labsetup.zip
seed@seed-VirtualBox:~/task1$ cat ciphertext.txt
ytn xqavhq yzhu  xu qzupvd ltmat qnncq vgxzy hmrty vbynh ytmq ixur qyhvurn
vlvhpq yhme ytn gvrrnh bnniq imsn v uxuvrnuvhmvu yxx

ytn vlvhpq hvan lvq gxxsnupnp gd ytn pncmqn xb tvhfnd lnmuqynmu vy myq xzyqny
vup ytn veevhnuy mceixqmxu xb tmq bmic axcevud vy ytn nup vup my lvq qtvenp gd
ytn ncnhrnuan xb cnyxx ymcnq ze givasrxlu eximymaq vhcavupd vaymfmqc vup
v uvymxuvi axufnhqvymxu vq ghmnb vup cvp vq v bnfnh phnvc vgxzy ltnytnh ytnhn
xzrty yx gn v ehnqmpnuy lmubhnd ytn qnvqxu pmpuy ozqy qnnc nkyhv ixur my lvq
nkyhv ixur gnavzqn ytn xqavhq lnhn cxfnp yx ytn bmhqy lnnsnup mu cvhat yx
vfxmp axubimaymur lmyt ytn aixqmur anhncxud xb ytn lmuynh xidcemaq ytvusq
ednxuratvur

xun gmr jznqymxu qzhhxzupmur ytmq dnvhq vavpncd vlvhpq mq txl xh mb ytn
anhncxud lmii vpphnqq cnyxx nqenamviid vbynh ytn rxipnu rixgnq ltmat gnavcn
v ozgmivuy axcmurxzy evhyd bxh ymcnq ze ytn cxfncnuy qenvhtnvpnp gd
exlnhbzi txiidlxxp lxcnu ltx tnienp hvmqn cmiimxuq xb pxiivhq yx bmrty qnkzvi
tvhvqqcnuy vhxzup ytn axzuyhd

qmruvimur ytnmh qzeexhy rxipnu rixgnq vyynupnnq qlvytnp ytncqnifnq mu givas
qexhynp iveni emuq vup qxzupnp xbb vgxzy qnkmqy exlnh mcgvivuanq bhxc ytn hnp
avheny vup ytn qyvrn xu ytn vmh n lvq aviinp xzy vgxzy evd munjzmyd vbynh
myq bxhcnh vuatxh avyy qvpinh jzmy xuan qtn invhunp ytvy qtn lvq cvsmur bvh
inqq ytvu v cvin axtxqy vup pzhmur ytn anhncxud uvyvimn exhycvu yxxs v gizuy
vup qvymqbdmur pmr vy ytn viicvin hxqynh xb uxcmuvynp pmhnayxhq txl axzip
ytvy gn yxeenp

vq my yzhuq xzy vy invqy mu ynhcq xb ytn xqavhq my ehxgvgid lxuy gn

lxcnu mufxifnp mu ymcnq ze qvmp ytvy viytxzrt ytn rixgnq qmrumbmnp ytn
mumymvymfnq ivzuat ytnd unfnh muynupnp my yx gn ozqy vu vlvhpq qnvqxu
avcevmru xh xun ytvy gnavcn vqqxamvynp xuid lmyt hnpavheny vaymxuq muqynvp
v qexsnqlxcvu qvmp ytn rhxze mq lxhsmur gntmup aixqnp pxxhq vup tvq qmuan
vcvqqnp  cmiimxu bxh myq inrvi pnbnuqn bzup ltmat vbynh ytn rixgnq lvq
bixxpnp lmyt ytxzqvupq xb pxuvymxuq xb  xh inqq bhxc enxein mu qxcn
axzuyhmnq
```

c. Ran freq.py on ciphertext.txt file to obtain the frequently occurring bigrams and trigrams. Appendix A contains the source code of freq.py and its output.

d.

```
seed@seed-VirtualBox:~/task1$ cat freq.py
#!/usr/bin/env python3

from collections import Counter
import re

TOP_K  = 20
N_GRAM = 3

# Generate all the n-grams for value n
def ngrams(n, text):
    for i in range(len(text) -n + 1):
        # Ignore n-grams containing white space
        if not re.search(r'\s', text[i:i+n]):
           yield text[i:i+n]

# Read the data from the ciphertext
with open('ciphertext.txt') as f:
    text = f.read()

# Count, sort, and print out the n-grams
for N in range(N_GRAM):
   print("-----------------------------------")
   print("{}-gram (top {}):".format(N+1, TOP_K))
   counts = Counter(ngrams(N+1, text))        # Count
   sorted_counts = counts.most_common(TOP_K)  # Sort
   for ngram, count in sorted_counts:
       print("{}: {}".format(ngram, count))   # Print
seed@seed-VirtualBox:~/task1$
```


seed@seed-VirtualBox:~/task1$ python3 freq.py
1-gram (top 20):
n: 488
y: 373
v: 348
x: 291
u: 280
q: 276
m: 264
h: 235
t: 183
i: 166
p: 156
a: 116
c: 104
z: 95
l: 90
g: 83
b: 83
r: 82
e: 76
d: 59
2-gram (top 20):
yt: 115
tn: 89
mu: 74
nh: 58
vh: 57
hn: 57
vu: 56
nq: 53
xu: 52
up: 46
xh: 45
yn: 44
np: 44
vy: 44
nu: 42
qy: 39
vq: 33
vi: 32
gn: 32
av: 31
3-gram (top 20):
ytn: 78

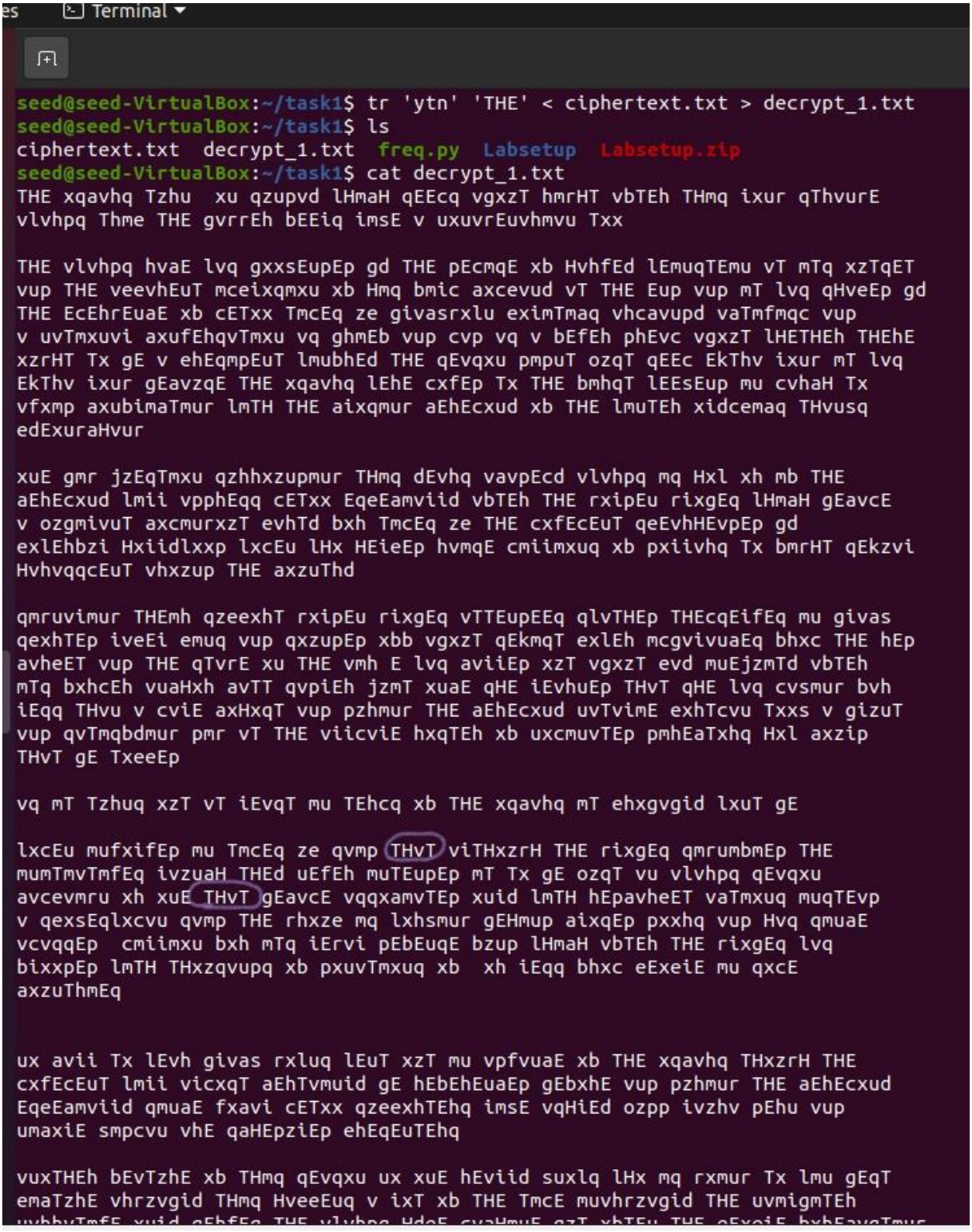

r: 82
e: 76
d: 59
2-gram (top 20):
yt: 115
tn: 89
mu: 74
nh: 58
vh: 57
hn: 57
vu: 56
nq: 53
xu: 52
up: 46
xh: 45
yn: 44
np: 44
vy: 44
nu: 42
qy: 39
vq: 33
vi: 32
gn: 32
av: 31
3-gram (top 20):
ytn: 78
vup: 30
mur: 20
ynh: 18
xzy: 16
mxu: 14
gnq: 14
ytv: 13
nqy: 13
vii: 13
bxh: 13
lvq: 12
nuy: 12
vyn: 12
uvy: 11
lmu: 11
nvh: 11
cmu: 11
tmq: 10
vhp: 10
seed@seed-VirtualBox:~/task1$

e. Observed “ytn” occurs 78 times, and the most common trigram is “THE”.

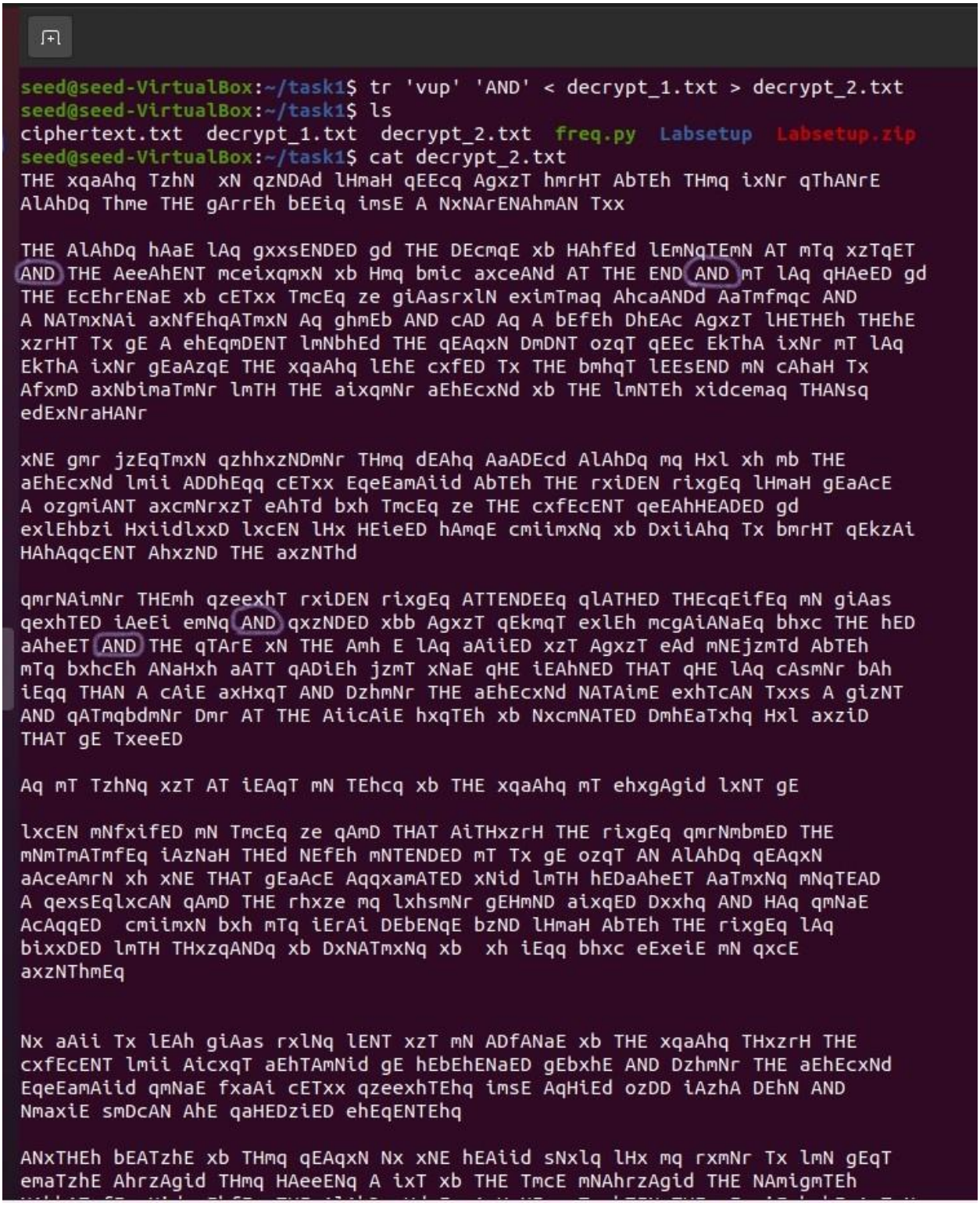
f. tr 'ytn' 'THE' < ciphertext.txt > decrypt_1.txt

g. Observed through the intermediate results and found the THvT => THAT. Also “vup” is the 2nd commonly occurring trigram in the cipher text, that corresponds to “AND” which is the 2nd commonly occurring trigram in english according to statistics.

h.



i. tr 'vup' 'AND' < decrypt_1.txt > decrypt_2.txt



j. Then observed

i) THEmR => THEIR, mN => IN, mT => IT (m => I, 3 matches)

ii) tr 'm' 'I' < decrypt_2.txt > decrypt_3.txt

k. Observed these words:

i) THhEE => THREE, THEIh => THEIR (h => R, 2 matches)

ii) tr 'h' 'R' < decrypt_3.txt > decrypt_4.txt

l. Observed:

i) DIREaTxR => DIRECTOR, RAaE => RACE, ANaHxR => ANCHOR (a => C, x => O, 2 matches for both)

ii) tr 'ax' 'CO' < decrypt_4.txt > decrypt_5.txt

```
seed@seed-VirtualBox:~/task1$ tr 'm' 'I' < decrypt_2.txt > decrypt_3.txt
seed@seed-VirtualBox:~/task1$ tr 'h' 'R' < decrypt_3.txt > decrypt_4.txt
seed@seed-VirtualBox:~/task1$ tr 'ax' 'CO' < decrypt_4.txt > decrypt_5.txt
seed@seed-VirtualBox:~/task1$ ls
ciphertext.txt  decrypt_1.txt  decrypt_2.txt  decrypt_3.txt  decrypt_4.txt  decrypt_5.txt  freq.py  Labsetup  Labsetup.zip
seed@seed-VirtualBox:~/task1$ cat decrypt_5.txt
THE OqCARq TzRN  ON qzNDAd lHICH qEEcq AgOzT RIrHT AbTER THIq iONr qTRANrE
AlARDq TRIe THE gArrER bEEiq iIsE A NONArENARIAN TOO

THE AlARDq RACE lAq gOOsENDED gd THE DEcIqE Ob HARfEd lEINqTEIN AT ITq OzTqET
AND THE AeeARENT IceiOqION Ob HIq bIic COceANd AT THE END AND IT lAq qHAeED gd
THE EcERrENCE Ob cETOO TIcEq ze giACsrOlN eOiITICq ARcCANDd ACTIfIqc AND
A NATIONAi CONfERqATION Aq gRIEb AND cAD Aq A bEfER DREAc AgOzT lHETHER THERE
OzrHT TO gE A eREqIDENT lINbREd THE qEAqON DIDNT ozqT qEEc EkTRA iONr IT lAq
EkTRA iONr gECAzqE THE OqCARq lERE cOfED TO THE bIRqT lEEsEND IN cARCH TO
AfOID CONbiICTINr lITH THE CiOqINr CEREcONd Ob THE lINTER OidceICq THANsq
edEONrCHANr

ONE gIr jzEqTION qzRROzNDINr THIq dEARq ACADEcd AlARDq Iq HOl OR Ib THE
CEREcONd lIii ADDREqq cETOO EqeECIAiid AbTER THE rOiDEN riOgEq lHICH gECAcE
A ozgIiANT COcINrOzT eARTd bOR TIcEq ze THE cOfEcENT qeEARHEADED gd
eOlERbzi HOiidlOOD lOcEN lHO HEieED RAIqE cIiiIONq Ob DOiiARq TO bIrHT qEkzAi
HARAqqcENT AROzND THE COzNTRd

qIrNAiINr THEIR qzeeORT rOiDEN riOgEq ATTENDEEq qlATHED THEcqEifEq IN giACs
qeORTED iAeEi eINq AND qOzNDED Obb AgOzT qEkIqT eOlER IcgAiANCEq bROc THE RED
CAReET AND THE qTArE ON THE AIR E lAq CAiiED OzT AgOzT eAd INEjzITd AbTER
ITq bORcER ANCHOR CATT qADiER jzIT ONCE qHE iEARNED THAT qHE lAq cAsINr bAR
iEqq THAN A cAiE COHOqT AND DzRINr THE CEREcONd NATAiIE eORIcAN TOOs A gizNT
AND qATIqbdINr DIr AT THE AiicAiE ROqTER Ob NOcINATED DIRECTORq HOl COziD
THAT gE TOeeED

Aq IT TzRNq OzT AT iEAqT IN TERcq Ob THE OqCARq IT eROgAgid lONT gE

lOcEN INfOifED IN TIcEq ze qAID THAT AiTHOzrH THE riOgEq qIrNIbIED THE
INITIATIfEq iAzNCH THEd NEfER INTENDED IT TO gE ozqT AN AlARDq qEAqON
CAceAIrN OR ONE THAT gECAcE AqqOCIATED ONid lITH REDCAReET ACTIONq INqTEAD
A qeOsEqlOcAN qAID THE rROze Iq lORsINr gEHIND CiOqED DOORq AND HAq qINCE
AcAqqED  cIiiION bOR ITq iErAi DEbENqE bzND lHICH AbTER THE riOgEq lAq
biOODED lITH THOzqANDq Ob DONATIONq Ob  OR iEqq bROc eEOeiE IN qOcE
COzNTRIEq


NO CAii TO lEAR giACs rOlNq lENT OzT IN ADfANCE Ob THE OqCARq THOzrH THE
cOfEcENT lIii AicOqT CERTAINid gE REbERENCED gEbORE AND DzRINr THE CEREcONd
EqeECIAiid qINCE fOCAi cETOO qzeeORTERq iIsE AqHiEd ozDD iAzRA DERN AND
NICOiE sIDcAN ARE qCHEDziED eREqENTERq

ANOTHER bEATzRE Ob THIq qEAqON NO ONE REAiid sNOlq lHO Iq sOINr TO lIN qEqT
```

m. Observed:

i) # AROzND => AROUND, TzRN => TURN (z => U)

ii) # DIr => DIG, RIrHT => RIGHT (r => G), rOiDEN => GOLDEN, iONr => LONG (r => G, i => L)

iii) # tr 'zri' 'UGL' < decrypt_5.txt > decrypt_6.txt

n. Observed:

i) # lHICH => WHICH, lILL => WILL, lIN => WIN, lINNER => WINNER (l => W)

ii) # ATTENDEEq => ATTENDEES, LEqq => LESS (q => S)

iii) # AbTER => AFTER, Obb => OFF, CONbLICTING => CONFLICTING (b => F)

iv) # tr 'lqb' 'WSF' < decrypt_6.txt > decrypt_7.txt

o. Observed

i) # ESeECIALLd => ESPECIALLY (e => P, d => Y)

ii) # tr 'ed' 'PY' < decrypt_7.txt > decrypt_8.txt

p. Observed

i) # COcPANY => COMPANY, TIcES (c => M)

ii) # gY => BY, AgOUT => ABOUT (g => B)

iii) # tr 'cg' 'MB' < decrypt_8.txt > decrypt_9.txt

q. Observe

i) # oUBILANT => JUBILANT, oUST => JUST (o => J)

ii) # WEEsEND => WEEKEND, THANsS => THANKS (s => K)

iii) # tr 'os' 'JK' < decrypt_9.txt > decrypt_10.txt

r. Observed

i) # HARfEY => HARVEY, ACTIfISM => ACTIfISM (f => V)

ii) # tr 'f' 'V' < decrypt_10.txt > decrypt_11.txt

s. Observed

i) # EkTRA => EXTRA (k => X)

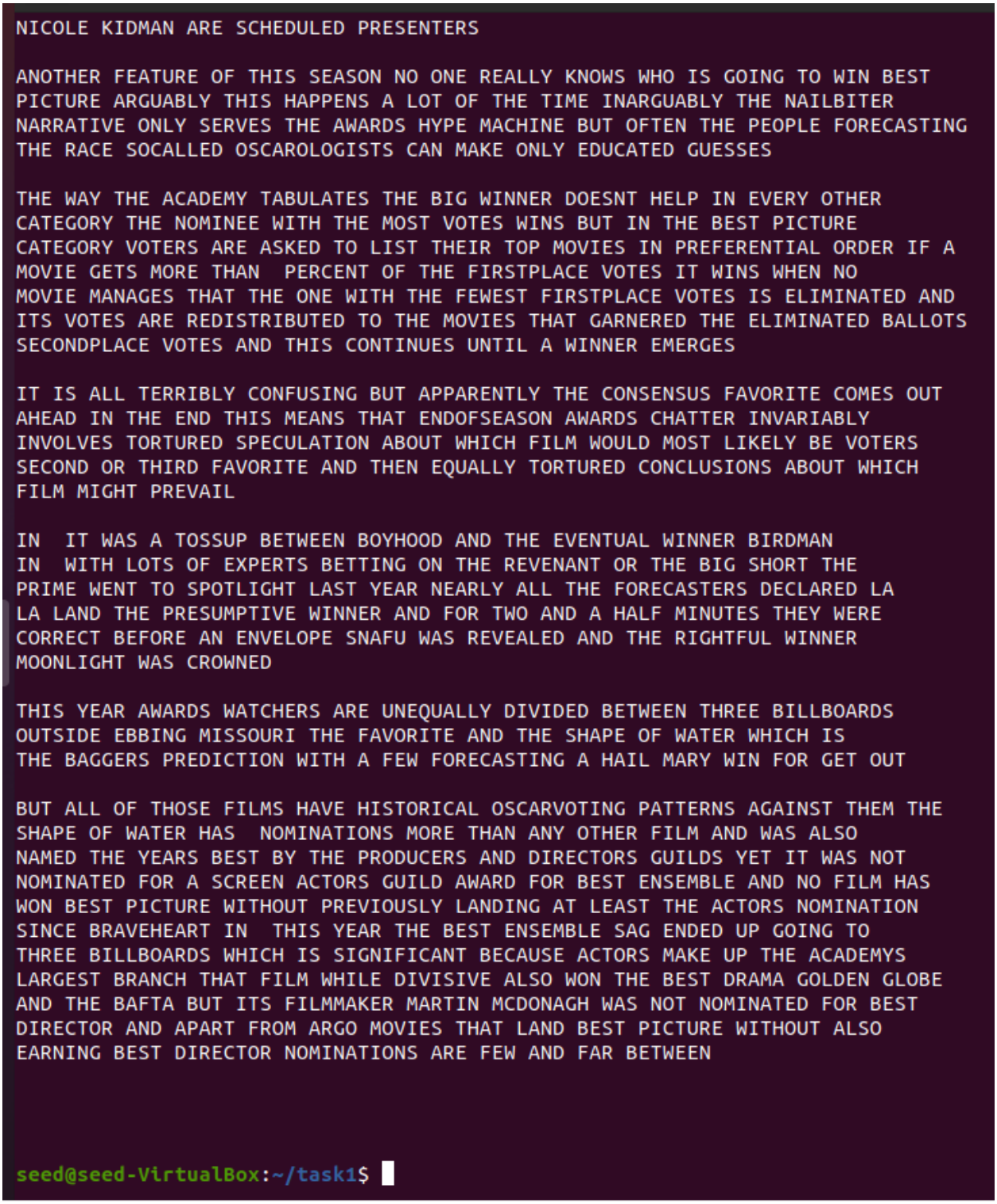
ii) # jUESTION => QUESTION (j => Q)

iii) # PRIwE => PRIME (w => M)

iv) # tr 'kjw' 'XQM' < decrypt_11.txt > decrypt_12.txt

t. Decryption complete. No more cipher letters left.

```
seed@seed-VirtualBox:~/task1$ tr 'zri' 'UGL' < decrypt_5.txt > decrypt_6.txt
seed@seed-VirtualBox:~/task1$ tr 'lqb' 'WSF' < decrypt_6.txt > decrypt_7.txt
seed@seed-VirtualBox:~/task1$ tr 'ed' 'PY' < decrypt_7.txt > decrypt_8.txt
seed@seed-VirtualBox:~/task1$ tr 'cg' 'MB' < decrypt_8.txt > decrypt_9.txt
seed@seed-VirtualBox:~/task1$ tr 'os' 'JK' < decrypt_9.txt > decrypt_10.txt
seed@seed-VirtualBox:~/task1$ tr 'f' 'V' < decrypt_10.txt > decrypt_11.txt
seed@seed-VirtualBox:~/task1$ tr 'kjw' 'XQM' < decrypt_11.txt > decrypt_12.txt
seed@seed-VirtualBox:~/task1$ cat decrypt_12.txt
THE OSCARS TURN  ON SUNDAY WHICH SEEMS ABOUT RIGHT AFTER THIS LONG STRANGE
AWARDS TRIP THE BAGGER FEELS LIKE A NONAGENARIAN TOO

THE AWARDS RACE WAS BOOKENDED BY THE DEMISE OF HARVEY WEINSTEIN AT ITS OUTSET
AND THE APPARENT IMPLOSION OF HIS FILM COMPANY AT THE END AND IT WAS SHAPED BY
THE EMERGENCE OF METOO TIMES UP BLACKGOWN POLITICS ARMCANDY ACTIVISM AND
A NATIONAL CONVERSATION AS BRIEF AND MAD AS A FEVER DREAM ABOUT WHETHER THERE
OUGHT TO BE A PRESIDENT WINFREY THE SEASON DIDNT JUST SEEM EXTRA LONG IT WAS
EXTRA LONG BECAUSE THE OSCARS WERE MOVED TO THE FIRST WEEKEND IN MARCH TO
AVOID CONFLICTING WITH THE CLOSING CEREMONY OF THE WINTER OLYMPICS THANKS
PYEONGCHANG

ONE BIG QUESTION SURROUNDING THIS YEARS ACADEMY AWARDS IS HOW OR IF THE
CEREMONY WILL ADDRESS METOO ESPECIALLY AFTER THE GOLDEN GLOBES WHICH BECAME
A JUBILANT COMINGOUT PARTY FOR TIMES UP THE MOVEMENT SPEARHEADED BY
POWERFUL HOLLYWOOD WOMEN WHO HELPED RAISE MILLIONS OF DOLLARS TO FIGHT SEXUAL
HARASSMENT AROUND THE COUNTRY

SIGNALING THEIR SUPPORT GOLDEN GLOBES ATTENDEES SWATHED THEMSELVES IN BLACK
SPORTED LAPEL PINS AND SOUNDED OFF ABOUT SEXIST POWER IMBALANCES FROM THE RED
CARPET AND THE STAGE ON THE AIR E WAS CALLED OUT ABOUT PAY INEQUITY AFTER
ITS FORMER ANCHOR CATT SADLER QUIT ONCE SHE LEARNED THAT SHE WAS MAKING FAR
LESS THAN A MALE COHOST AND DURING THE CEREMONY NATALIE PORTMAN TOOK A BLUNT
AND SATISFYING DIG AT THE ALLMALE ROSTER OF NOMINATED DIRECTORS HOW COULD
THAT BE TOPPED

AS IT TURNS OUT AT LEAST IN TERMS OF THE OSCARS IT PROBABLY WONT BE

WOMEN INVOLVED IN TIMES UP SAID THAT ALTHOUGH THE GLOBES SIGNIFIED THE
INITIATIVES LAUNCH THEY NEVER INTENDED IT TO BE JUST AN AWARDS SEASON
CAMPAIGN OR ONE THAT BECAME ASSOCIATED ONLY WITH REDCARPET ACTIONS INSTEAD
A SPOKESWOMAN SAID THE GROUP IS WORKING BEHIND CLOSED DOORS AND HAS SINCE
AMASSED  MILLION FOR ITS LEGAL DEFENSE FUND WHICH AFTER THE GLOBES WAS
FLOODED WITH THOUSANDS OF DONATIONS OF  OR LESS FROM PEOPLE IN SOME
COUNTRIES


NO CALL TO WEAR BLACK GOWNS WENT OUT IN ADVANCE OF THE OSCARS THOUGH THE
MOVEMENT WILL ALMOST CERTAINLY BE REFERENCED BEFORE AND DURING THE CEREMONY
ESPECIALLY SINCE VOCAL METOO SUPPORTERS LIKE ASHLEY JUDD LAURA DERN AND
NICOLE KIDMAN ARE SCHEDULED PRESENTERS
```



Appendix A: Source code of freq.py and output of running it is below.

```
#!/usr/bin/env python3
```

```
from collections import Counter
import re

TOP_K  = 20
N_GRAM = 3

# Generate all the n-grams for value n
def ngrams(n, text):
    for i in range(len(text) -n + 1):
    # Ignore n-grams containing white space
    if not re.search(r'\s', text[i:i+n]):
        yield text[i:i+n]

# Read the data from the ciphertext
with open('ciphertext.txt') as f:
    text = f.read()

# Count, sort, and print out the n-grams
for N in range(N_GRAM):
  print("-----------------------------------")
  print("{}-gram (top {}):".format(N+1, TOP_K))
  counts = Counter(ngrams(N+1, text))             # Count
```

```
        sorted_counts = counts.most_common(TOP_K)  # Sort
        for ngram, count in sorted_counts:
            print("{}: {}".format(ngram, count))   # Print
```

```
-----------------------------------
1-gram (top 20):
n: 488
y: 373
v: 348
x: 291
u: 280
q: 276
m: 264
h: 235
t: 183
i: 166
p: 156
a: 116
c: 104
z: 95
l: 90
g: 83
b: 83
r: 82
e: 76
d: 59
-----------------------------------
2-gram (top 20):
yt: 115
tn: 89
mu: 74
```

nh: 58
vh: 57
hn: 57
vu: 56
nq: 53
xu: 52
up: 46
xh: 45
yn: 44
np: 44
vy: 44
nu: 42
qy: 39
vq: 33
vi: 32
gn: 32
av: 31

3-gram (top 20):
ytn: 78
vup: 30
mur: 20
ynh: 18
xzy: 16
mxu: 14
gnq: 14
ytv: 13
nqy: 13
vii: 13
bxh: 13
lvq: 12
nuy: 12

vyn: 12
uvy: 11
lmu: 11
nvh: 11
cmu: 11
tmq: 10
vhp: 10

Task 2: Encryption using Different Cipher and Modes:

1. What are the differences between CBC, OFB, CRT cipher mode based on the table below?

In CBC (Cipher Block Chaining), the previous cipher block is XORed with the next plain text block, which forms the input to the encryption algorithm that generates the next cipher block. The very first XOR input comes from the IV (initialization vector). Since there is no direct relation between the plain text and cipher text, i.eThe same plain text blocks do not result in the same ciphertext blocks, CBC is a good encryption mechanism. The chaining dependency from the previous encryption step to the next step limits the encryption to happen in a sequential manner, however decryption can be parallelized.

OFB (Output Feedback Mode) encrypts the IV (initialization vector) and uses it not only for XOR with plain text to generate a cipher block, but also transmits the encrypted output to the next encryption step. The chain from the first step to next is similar to CBC, however unlike CBC the next steps do not have a dependency on the previous cipher blocks. This reduction of dependency between the cipher generation process on previous cipher blocks leads to OFB being resistant towards bit transmission errors. Neither encryption nor decryption process can be parallelized in OFB method.

CTR (Counter Mode) implements a simple counter based cipher implementation. Unlike CBC and OFB there is no chain from one step to another in CTR. The IV is used as a first counter, and a formula (that utilizes the encryption algorithm itself) is used to generate separate counters (or vectors) for each step. Each encrypted counter is XORed with the plain text block to generate a cipher block. Since there is no chain, CTR blocks can be parallelized for encryption or decryption. Similar to OFB it is also well resistant to bit transmission errors as it too avoids the dependency on previous cipher blocks.

	Plaintext file size	Encrypted file size
ECB	26(assuming in bytes)	32 bytes(i.e., two 128 bit blocks)
CBC	26	32 bytes
OFB	26	32 bytes

2. Are the sizes of plaintext and ciphertext different? Explain Why?

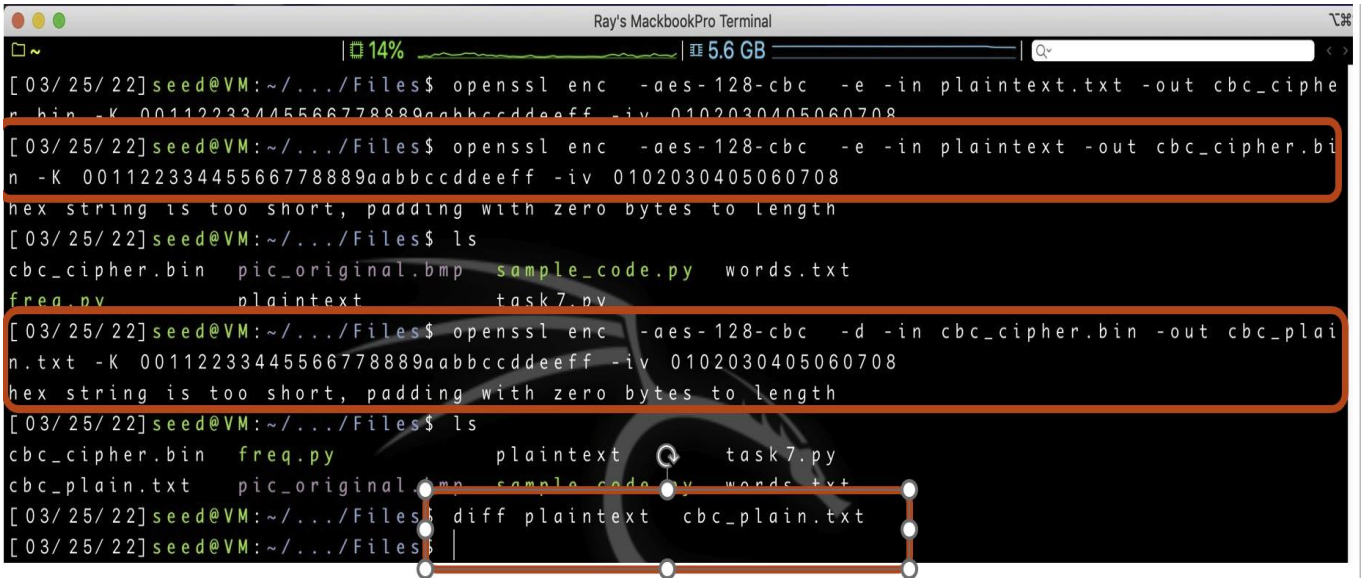
We can consider the sizes of plaintext and ciphertext as the same, except for one caveat. That is each block of plaintext is exactly the same in size with the ciphertext block, except for the last block in plaintext which can be less than 128 bits, in which case it is padded to generate a 128 bit ciphertext block.

3. Provide and explain Task2 Screenshots

CBC:

Encrypt and decrypt with aes-128-cbc mode -K 00112233445566778889aabbccddeeff
-iv 0102030405060708

And then use diff function to compare with the plaintext after decrypting and original plaintext

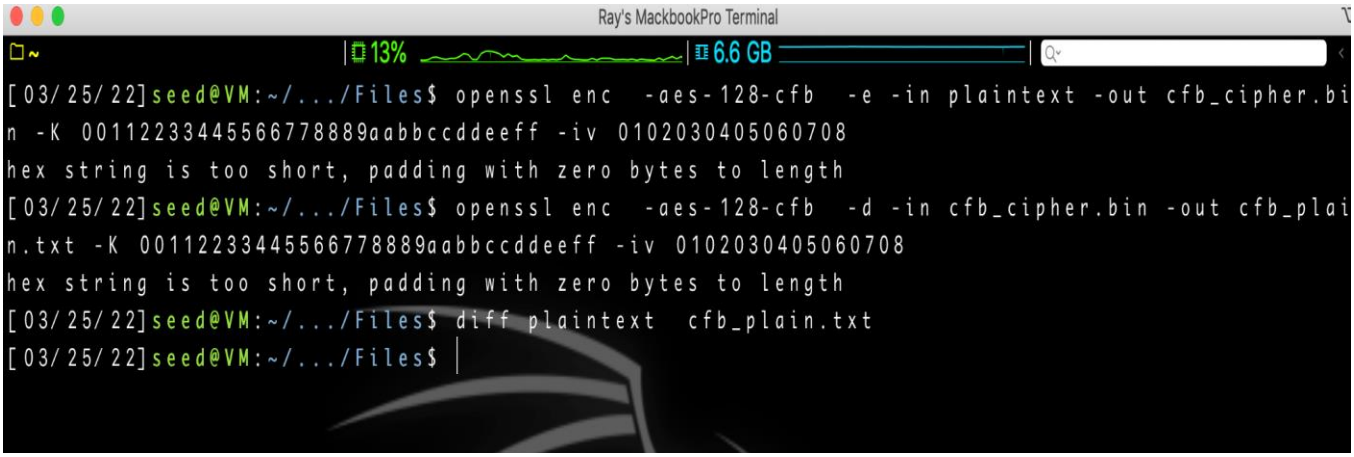


CFB:

Encrypt and decrypt with aes-128-cfb mode -K 00112233445566778889aabbccddeeff

-iv 0102030405060708

And then use diff function to compare with the plaintext after decrypting and original plaintext

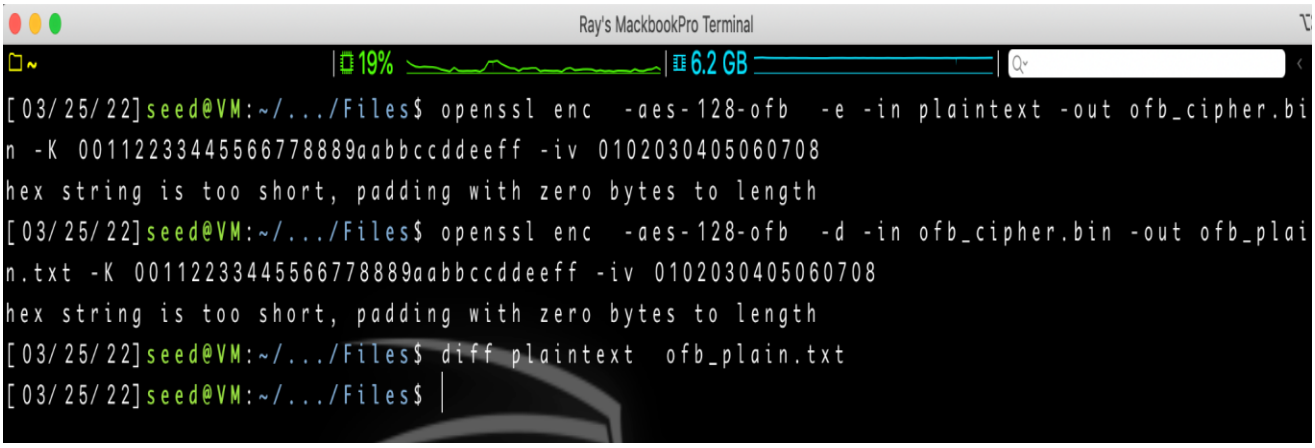


OFB:

Encrypt and decrypt with aes-128-ofb mode -K 00112233445566778889aabbccddeeff

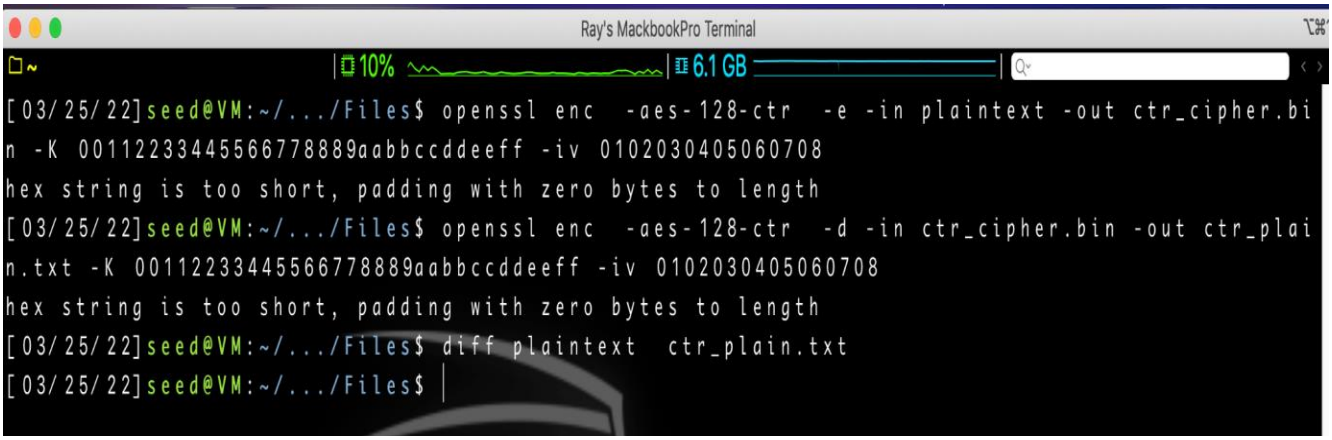
-iv 0102030405060708

And then use diff function to compare with the plaintext after decrypting and original plaintext



CTR:

Encrypt and decrypt with aes-128-ctr mode -K 00112233445566778889aabbccddeeff
-iv 0102030405060708
And then use diff function to compare with the plaintext after decrypting and original plaintext



Task 3: Encryption Modes – ECB vs. CBC:

1. What is the difference between ECB and CBC mode?

ECB (Electronic code book) performs direct encryption of a plain text block with a symmetric key to generate a ciphertext block. There is a direct relationship between the plaintext and ciphertext, meaning the same plaintext blocks regardless of where they occur in the plaintext file, always generate the exact same ciphertext blocks. Though there is a basic advantage that all block encryption steps of ECB can be parallelized, it is prone to cryptanalysis attacks where an attacker can observe and create known mappings that can be further used to break other ciphertext blocks. CBC (Cipher Block Chaining) solves this problem by using an IV (initialization vector) to XOR the first plain text block before encrypting to generate the cipher block, and subsequently uses the previous cipher block as the IV for next block encryption. Since the vector that is used for XOR at each step comes from the previous step's cipher block, the same plaintext block patterns will always generate different ciphertext blocks, thereby solving the problem ECB suffers from. However, the chain introduced in CBC leads to a limitation that the encryption of each block needs to happen sequentially, though decryption can be parallelized.

2. Which modes do you think perform better in encrypting the image? Why?

Since ECB mode generates the same ciphertext block for the same plaintext blocks, using it for encrypting images results in insecure encryption as demonstrated in the following figure obtained from Wikipedia. CBC performs better as shown in the rightmost column, where same plaintext blocks lead to different ciphertext blocks because of the dependency introduced in each encryption step to use the previous ciphertext block.

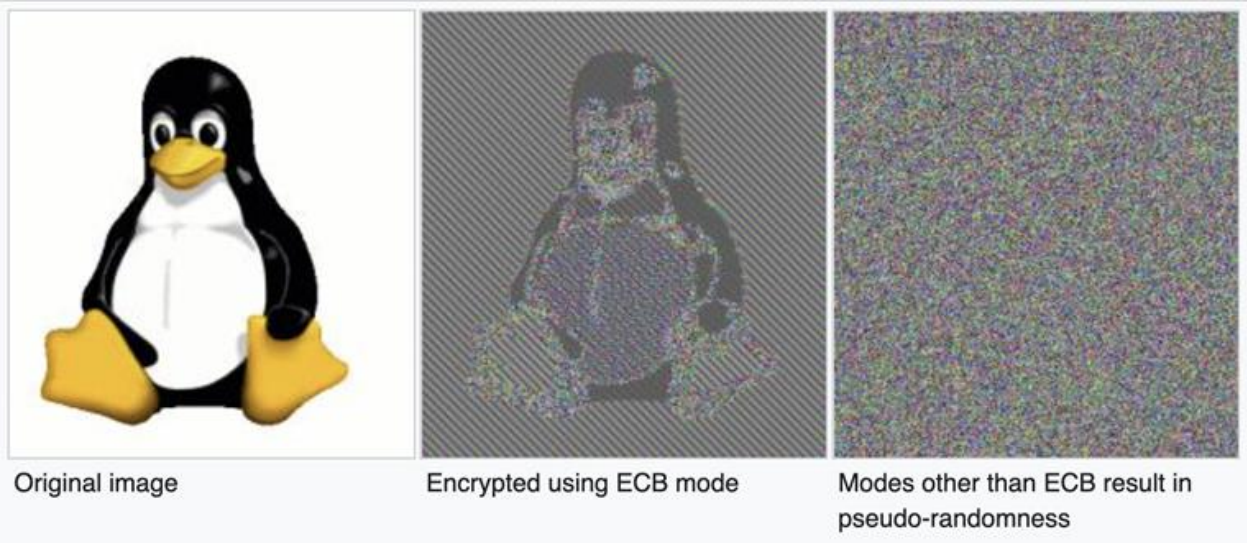
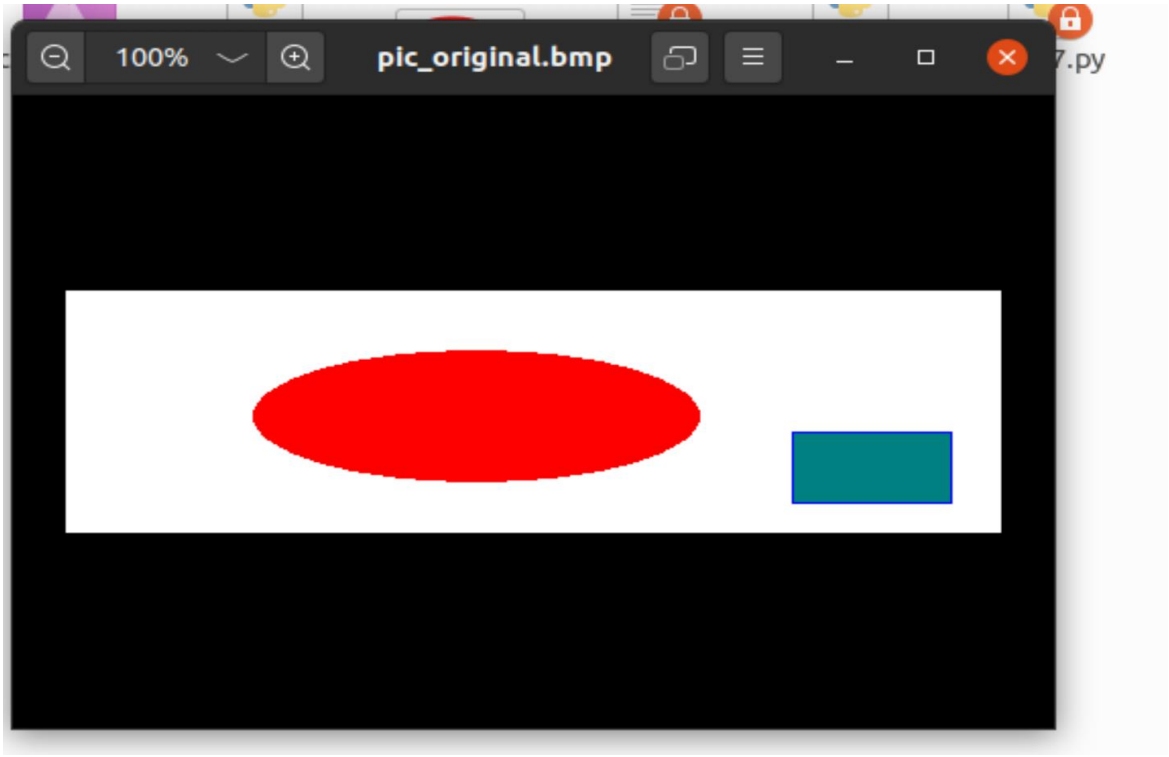


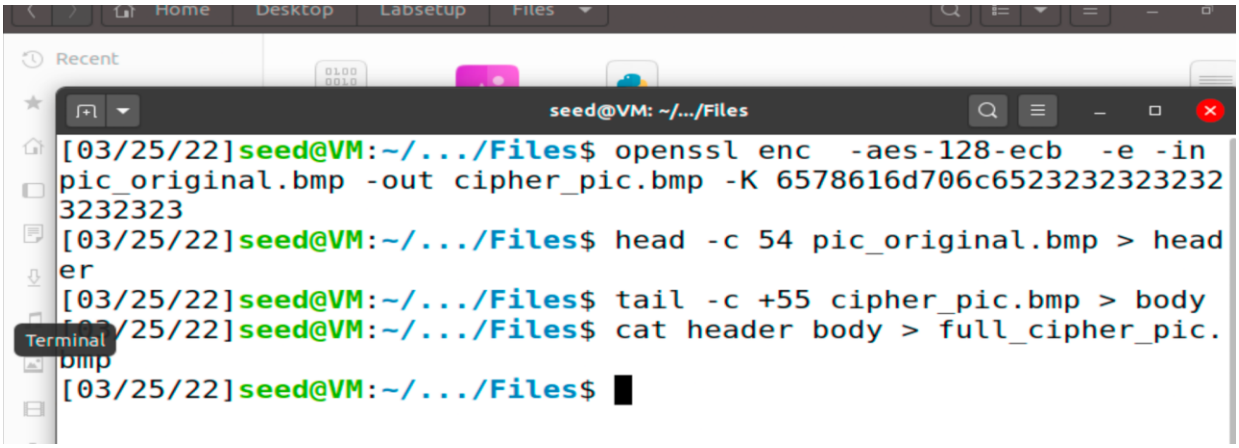
Figure 1

3. Provide and explain Task3 Screenshots.

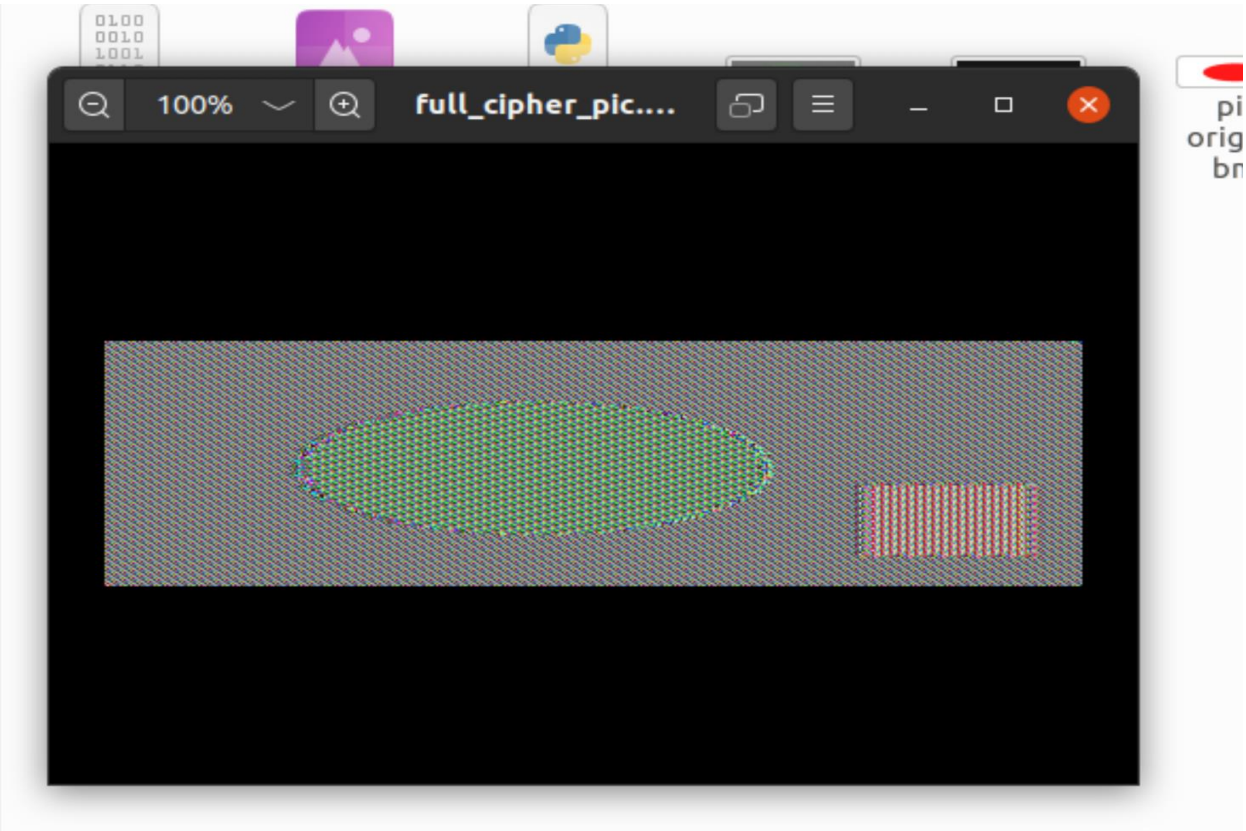
ECB Mode:

Encrypt the original .bmp picture with aes-128-ecb mode
-K d34c739f59a84d9b61c0f2883efa7bbc and then adjust the header to make the picture openable.





The encrypted one:



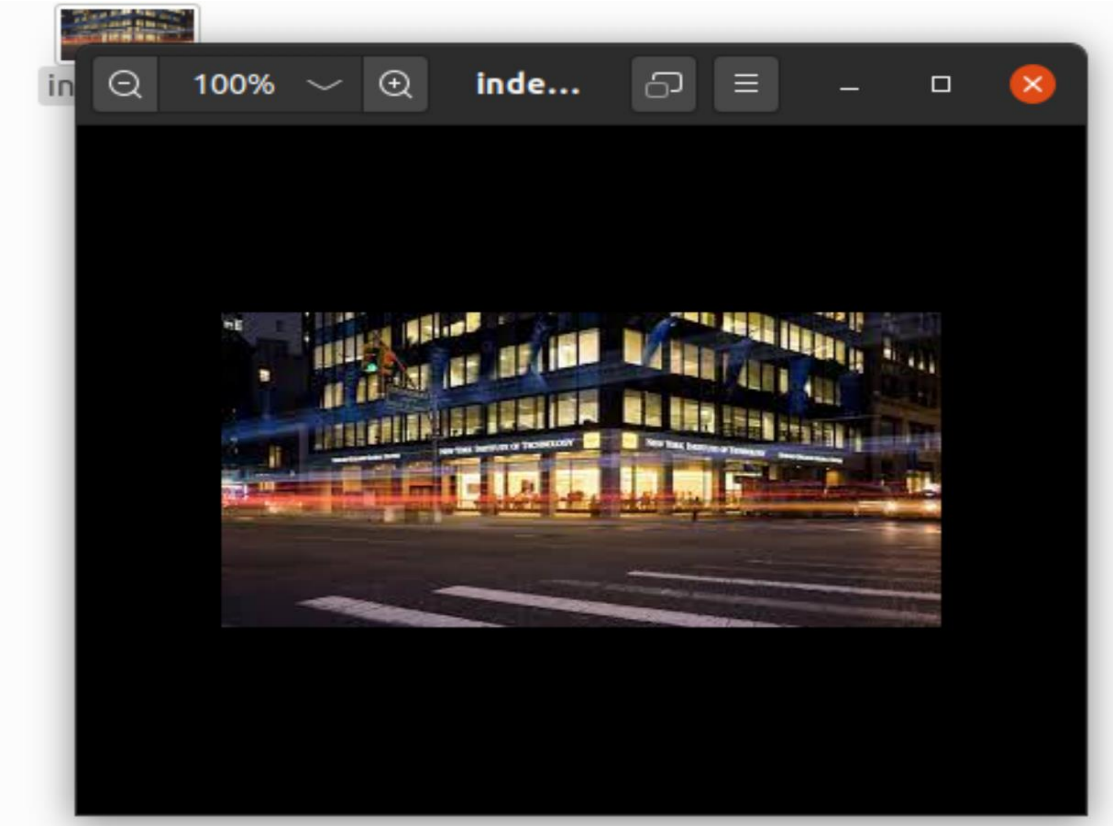
Explanation:

It is similar to the original image in several ways because it divides the file into 128-bit blocks and uses the AES for encryption. If two blocks are identical in the original image, encrypted one and unencrypted one will remain identical.

CBC Mode:

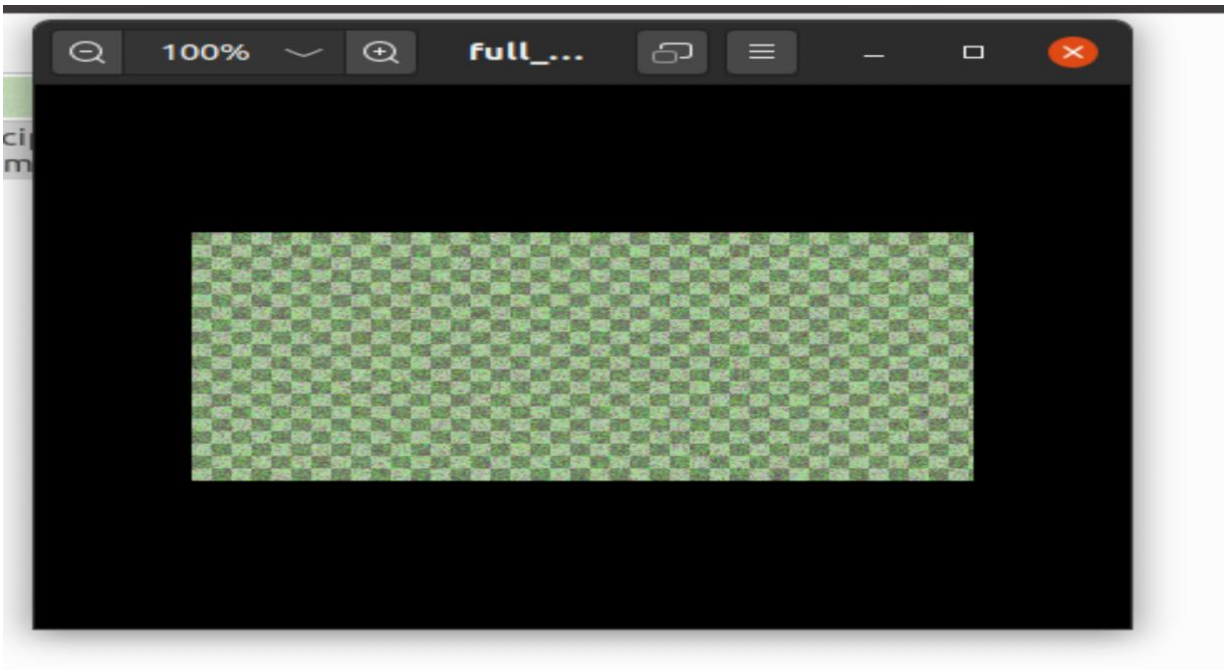
Encrypt the original .bmp picture with aes-128-cbc mode -K 00112233445566778889aabbccddeeff -iv d34c739f59a84d9b61c0f2883efa7bbc and then adjust the header to make the picture openable.

The original picture




```
seed@VM: ~/Downloads
[03/25/22]seed@VM:~/Downloads$ openssl enc  -aes-128
-cbc -e -in index.bmp -out cipher.bmp -K 00112233445
566778889aabbccddeeff -iv d34c739f59a84d9b61c0f2883e
fa7bbc
[03/25/22]seed@VM:~/Downloads$ head -c 54 index.bmp
> header
[03/25/22]seed@VM:~/Downloads$ tail -c +55 cipher.bm
p > body
[03/25/22]seed@VM:~/Downloads$ cat header body > ful
l_cipher.bmp
[03/25/22]seed@VM:~/Downloads$
```

The encrypted one:



Explanation:

It is two blocks that are identical in the original image, encrypted one and unencrypted one will remain identical. Otherwise, it will be different.

Task 4: Padding:

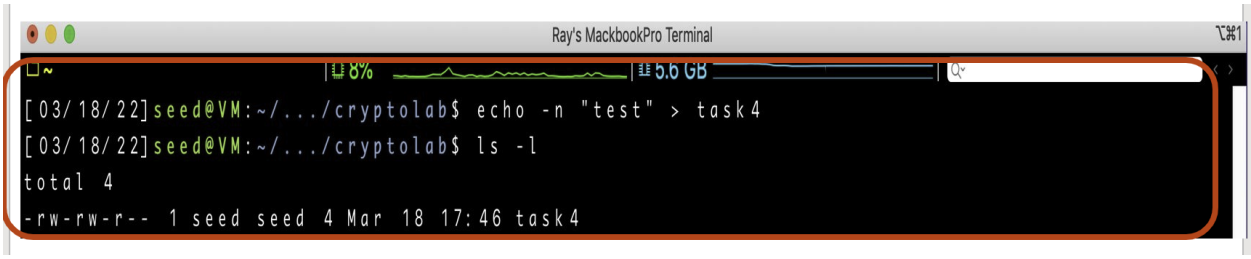
1. Which modes of operations used padding and which ones not? Why?

In the modes of ECB and CBC, if a length of the plaintext is not the same as block size, this should add some padding string to match with a length of block size. A padding scheme is a way to prevent some cryptanalysts from breaking encryption to get the plaintext.

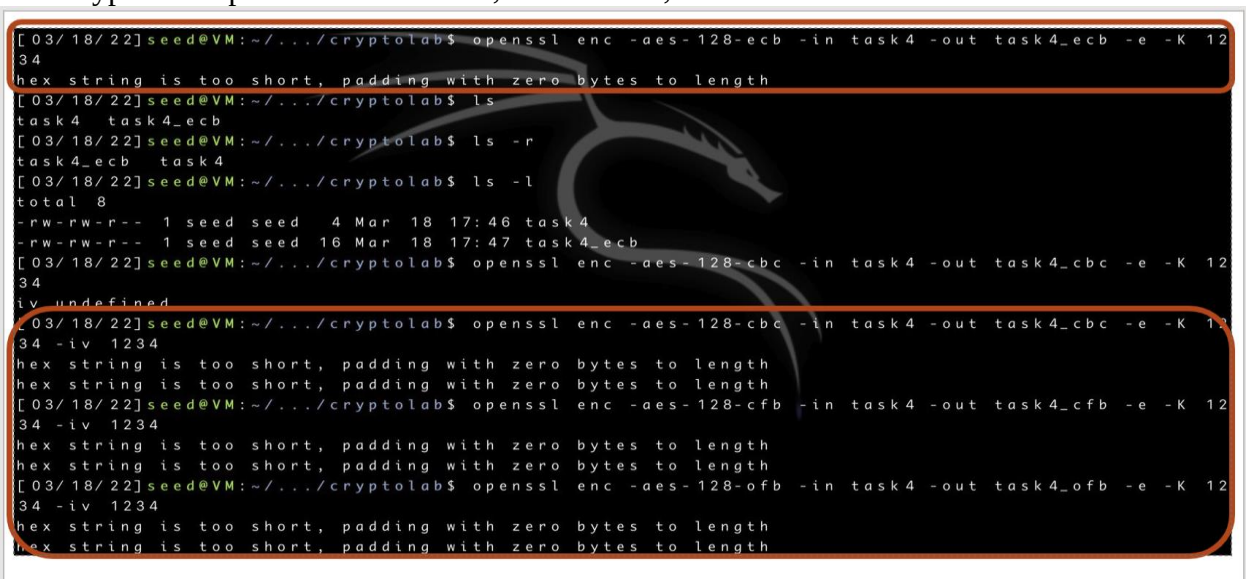
Besides this, other modes like OFB, CFB and CTR do not need to add the padding space because the length of ciphertext is the same as the size of plaintext, and all of these three modes will not encrypt plaintext directly which just involves plaintext bitwise XOR with ciphertext.

2. Task4 screenshots results are as follows

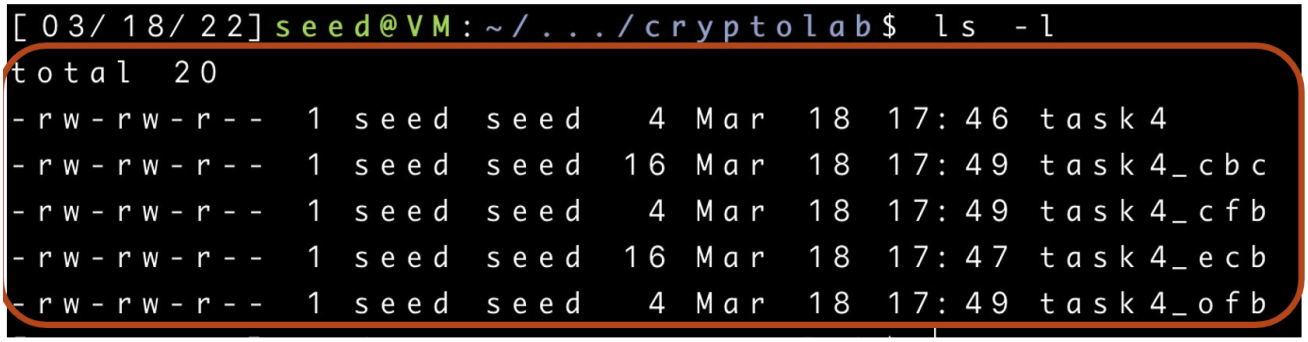
a. Use ECB, CBC, CFB, and OFB modes to encrypt the “task4” file that contains 4 bytes.



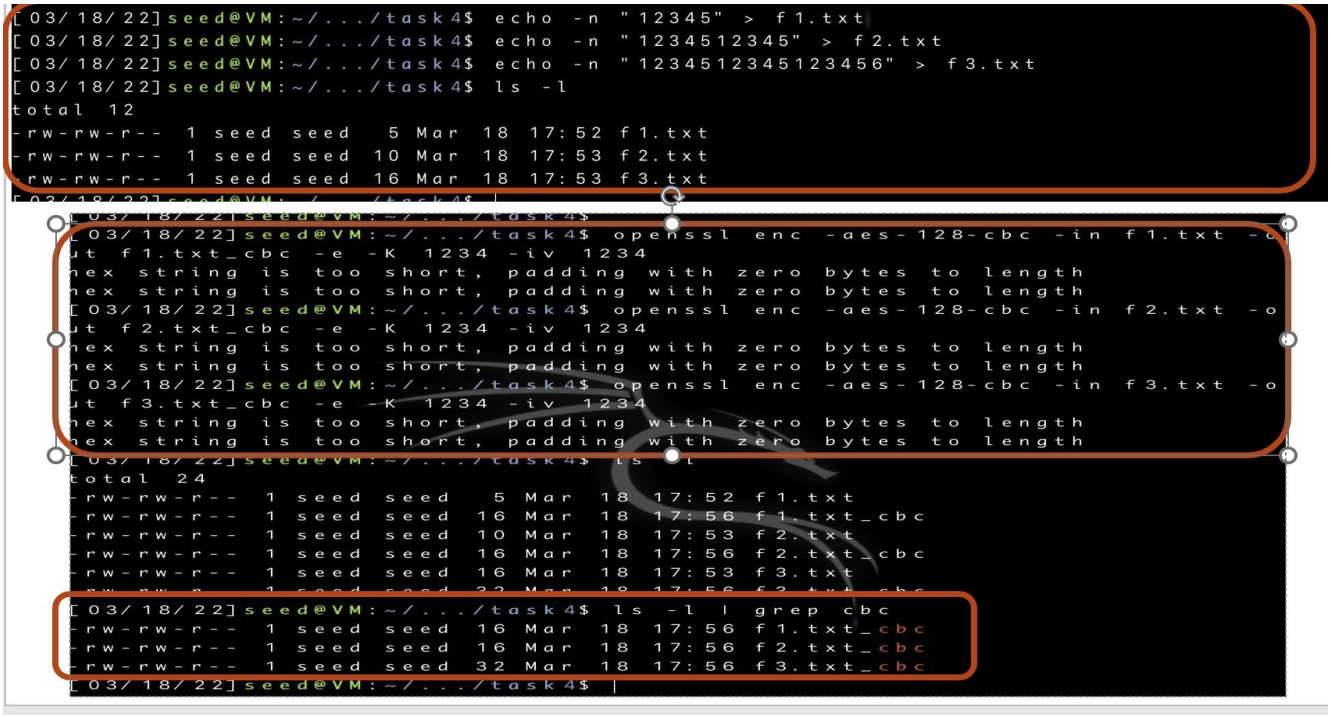
b. Encrypt with OpenSSL aes-128-ecb, aes-128-cbc, aes-128-cfb and aes-128-ofb



c. This shows CBC and ECB mode use the padding scheme during AES-128 encryption.

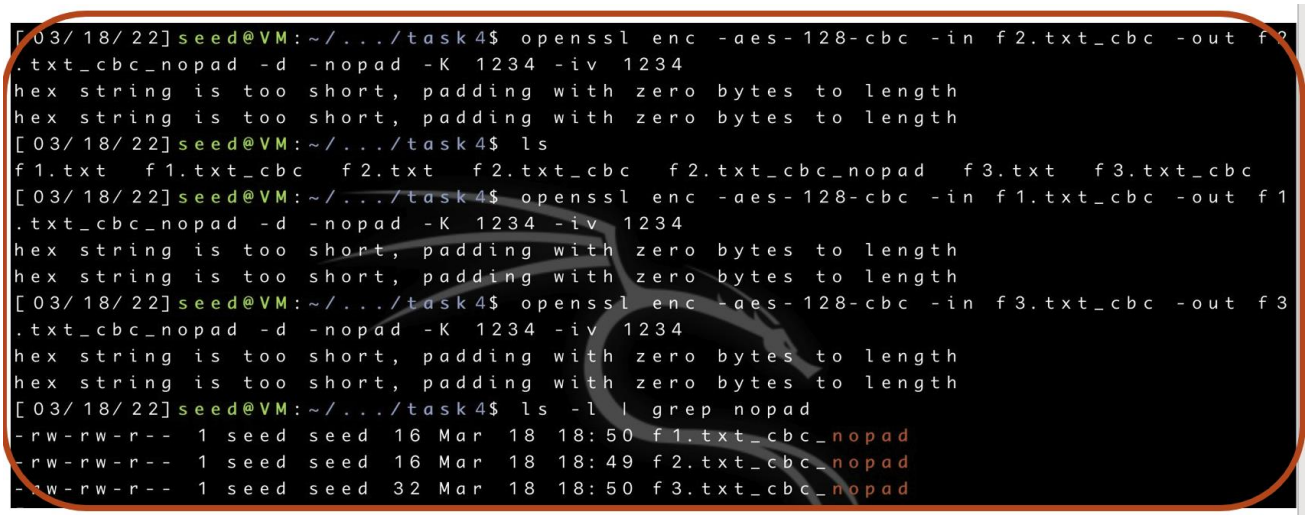


d. Create three files, which contain 5 bytes, 10 bytes, and 16 bytes; therefore, encrypt the f1.txt, f2.txt and f3.txt files with aes-128-cbc.



e. Using aes-128-cbc to decrypt f1.txt_cbc, f2.txt_cbc and f3.txt_cbc files with parameters -nopad respectively.

-nopad will not remove padding space during decryption.

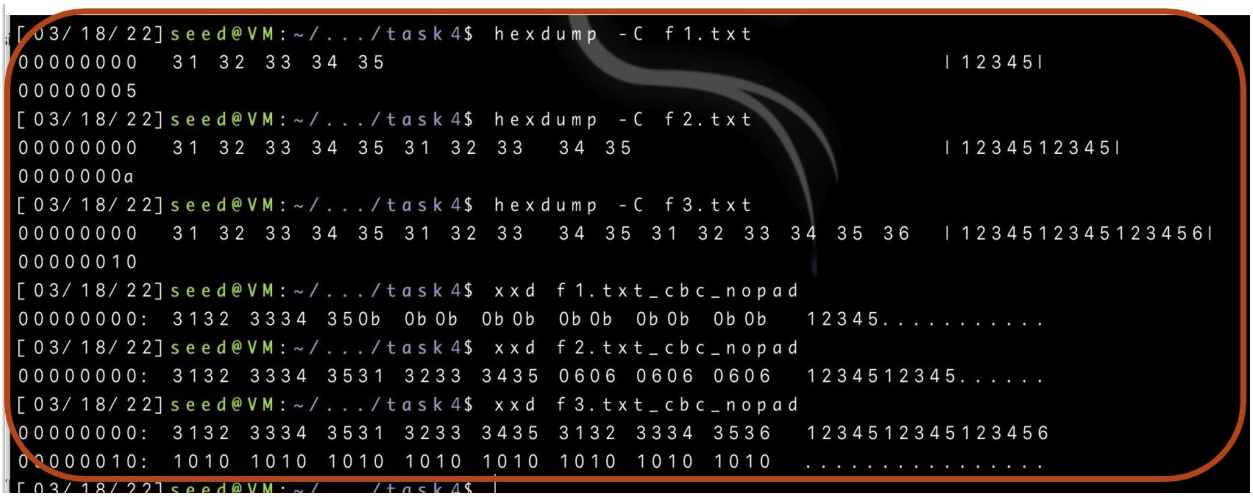


f. The contents of decrypted files are also the same as the original files, and this shows how CBC modes use a padding scheme to the f1.txt, f2.txt and f3.txt files.

f1.txt_cbc_nopad contains 5 Bytes so empty space will be 0x10 - 0x05 = 0x0b (hexadecimal)

f2.txt_cbc_nopad contains 10 Bytes so empty space will be 0x10 - 0x0a = 0x06 (hexadecimal)

f3.txt_cbc_nopad contains 16 Bytes so empty space will be 0x10 - 0x10 = 0x00 (hexadecimal), which does not need padding.



Task 5: Error Propagation – Corrupted Cipher Text:

1. What does Error propagation mean?

a. The event of error propagation is when a bit error is the replacement of a ‘0’ bit for a ‘1’ bit, or vice versa. These errors originated in the transmission channel as a result of problems and disturbance in communication. Then, the probability of Plain text error is at the same time the bit error probability in the cryptogram. Errors in the cryptogram produce errors in the decrypted plaintext.

2. Which mode of operation is worse in error propagation? Why?

a. The modes ECB, CBC and CFB, the RBE Causes more errors in the plaintext and cryptogram , while for OFB and CTR modes only the SBE type of error propagation can occur by only one bit. ECB is worse than CBC.
b. Because CBC and CBF and so on have more complex algorithms which provide output in ciphertext and are logically calculated before entering in the next block to be cipher.

3. Provide and explain Task5 Screenshots

a. We created a file called task5-1 with size more than 1000 bitsas requested by the lab. It shows in the next image.

```
-rw-rw-r--  1 seed seed  1368 Mar 24 21:35 task5-1
drwxr-xr-x  2 seed seed  4096 Nov 24  2020 Templates
-rw-r-----  1 seed seed     5 Jan 31 17:55 .vboxclient-clipboard.pid
-rw-r-----  1 seed seed     5 Jan 31 17:55 .vboxclient-display-svga-x11.pid
-rw-r-----  1 seed seed     5 Jan 31 17:55 .vboxclient-draganddrop.pid
-rw-r-----  1 seed seed     5 Jan 31 17:55 .vboxclient-seamless.pid
drwxr-xr-x  2 seed seed  4096 Nov 24  2020 Videos
[03/24/22]seed@VM:~$ cat task5-1
hello, we are Nafessa, Ray and Jairo and this is the task 5 of the assigement 3
Hopefully it will work
```

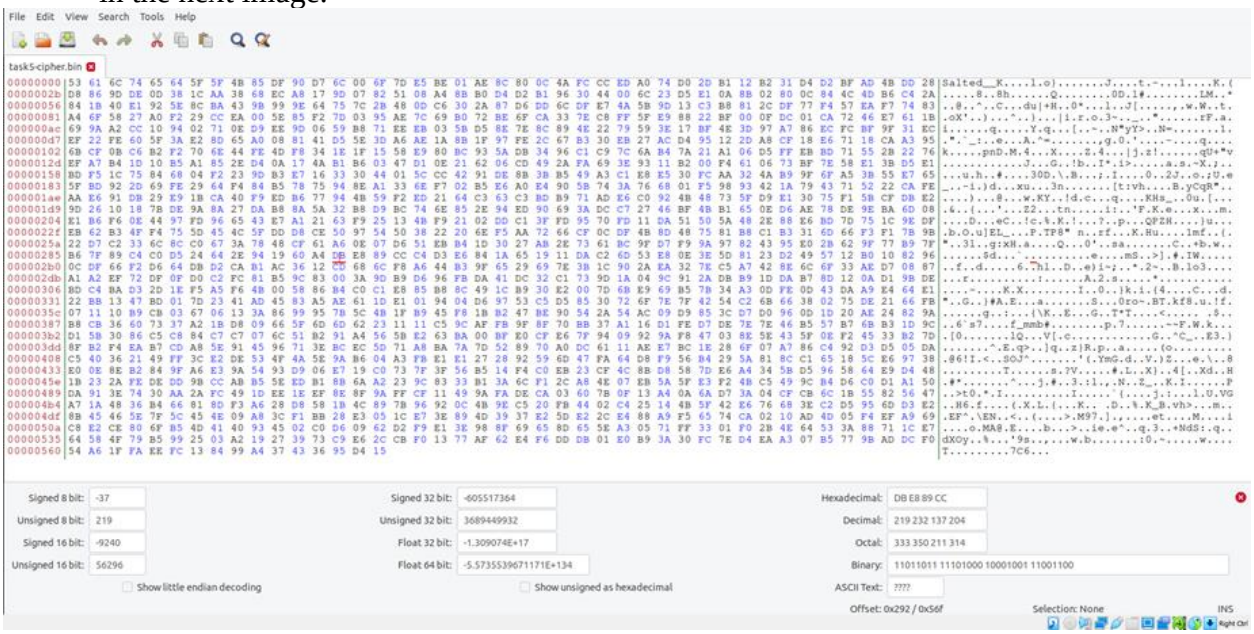
b. The file contains names of the team members and an output of the Ifconfig command, to ensure the size of the file fits the requirement.

```
[03/24/22]seed@VM:~$ cat task5-1
hello, we are Nafessa, Ray and Jairo and this is the task 5 of the assigement 3
Hopefully it will work


docker0: flags=4099<UP,BROADCAST,MULTICAST>  mtu 1500
        inet 172.17.0.1  netmask 255.255.0.0  broadcast 172.17.255.255
        ether 02:42:de:ca:f2:42  txqueuelen 0  (Ethernet)
        RX packets 0  bytes 0 (0.0 B)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 0  bytes 0 (0.0 B)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

enp0s3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 10.0.2.15  netmask 255.255.255.0  broadcast 10.0.2.255
        inet6 fe80::1caa:9e58:ec70:c17b  prefixlen 64  scopeid 0x20<link>
        ether 08:00:27:64:33:c3  txqueuelen 1000  (Ethernet)
        RX packets 11243  bytes 15616398 (15.6 MB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 2213  bytes 204356 (204.3 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING>  mtu 65536
        inet 127.0.0.1  netmask 255.0.0.0
        inet6 ::1  prefixlen 128  scopeid 0x10<host>
        loop  txqueuelen 1000  (Local Loopback)
        RX packets 411  bytes 32169 (32.1 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 411  bytes 32169 (32.1 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

[03/24/22]seed@VM:~$
[03/24/22]seed@VM:~$
```

c. Following image shows that the file “task5-1” is encrypted with the final name ‘task-cipher.bin’

```
[03/24/22]seed@VM:~$ openssl enc -aes-128-cbc -e -in task5-1 -out task5-cipher.bin
enter aes-128-cbc encryption password:
Verifying - enter aes-128-cbc encryption password:
*** WARNING : deprecated key derivation used.
Using -iter or -pbkdf2 would be better.
[03/24/22]seed@VM:~$ ls
Desktop  Documents  Downloads  Music  Pictures  Public  task5  task5-1  task5-cipher.bin  Templates  Videos
[03/24/22]seed@VM:~$
```

d. With the command bless we edit the file and remove one bit from the crypto text as shown in the next image.



e. With ECB mode when a file is decrypted, the plain text is recover partially as it show in the next image.

f. WE did the same procedure with a different file, in this case we use AES-ECB to encrypt

```
-rw-rw-r--  1 seed seed     0 Mar 24 22:20 task-5-ecb-decrypt
drwxr-xr-x  2 seed seed  4096 Nov 24  2020 Templates
-rw-r-----  1 seed seed     5 Jan 31 17:55 .vboxclient-clipboard.pid
-rw-r-----  1 seed seed     5 Jan 31 17:55 .vboxclient-display-svga-x11.pid
-rw-r-----  1 seed seed     5 Jan 31 17:55 .vboxclient-draganddrop.pid
-rw-r-----  1 seed seed     5 Jan 31 17:55 .vboxclient-seamless.pid
drwxr-xr-x  2 seed seed  4096 Nov 24  2020 Videos
[03/24/22]seed@VM:~$ cat task-5-ecb-decrypt
[03/24/22]seed@VM:~$ openssl enc -aes-128-ecb -d -in task5-cipher-ecb.bin -out task-5-ecb-decrypt
enter aes-128-ecb decryption password:
bad magic number
[03/24/22]seed@VM:~$ cat task-5-ecb-decrypt
[03/24/22]seed@VM:~$
```

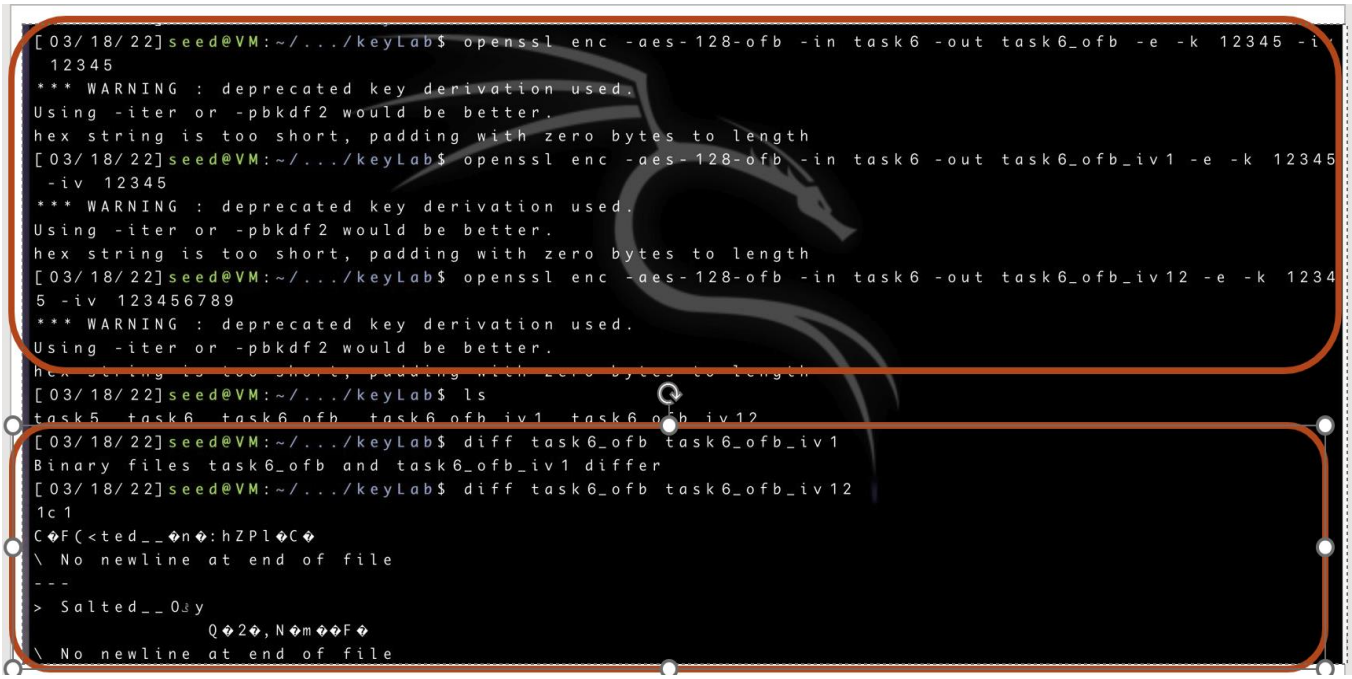
g. We were not able to retrieve any plain text after this operation.

Task 6: Initial Vector (IV) and Common Mistake:

1. What characteristics make IV secure?

The below screenshots referred to Task 6.1 IV experiment indicate that if the encrypted file task6_ofb and task6_ofb_iv1 with same Key and IV which is the number 12345, this will have no difference via the diff function that can check the binary files are the same or not; while task6_ofb and task6_ofb_iv12 with the same keys are different because of different IV.

Overall, the difference of IV can enhance the complexity of encryption keys.



2. Which mode of operation is not using IV? How can I make it more secure?

The mode of ECB is not using IV and encrypts plaintext block-by-block separately, so it lacks the diffusion scheme and the complexity of encryption. However, adding some random bits into plaintext can increase the security when encrypting the plaintext with ECB mode.

3. What is the chosen-plaintext attack? What mistake in IV can cause a chosen-plaintext attack?

In a chosen-plaintext attack, the attacker can specify his plaintext, which he can then encrypt or sign. He can carefully construct it in order to understand the algorithm's characteristics. The mistake in IV is that the attacker can predict the next IV is used so it can apply and choose the plaintext which is used for the further encryption.

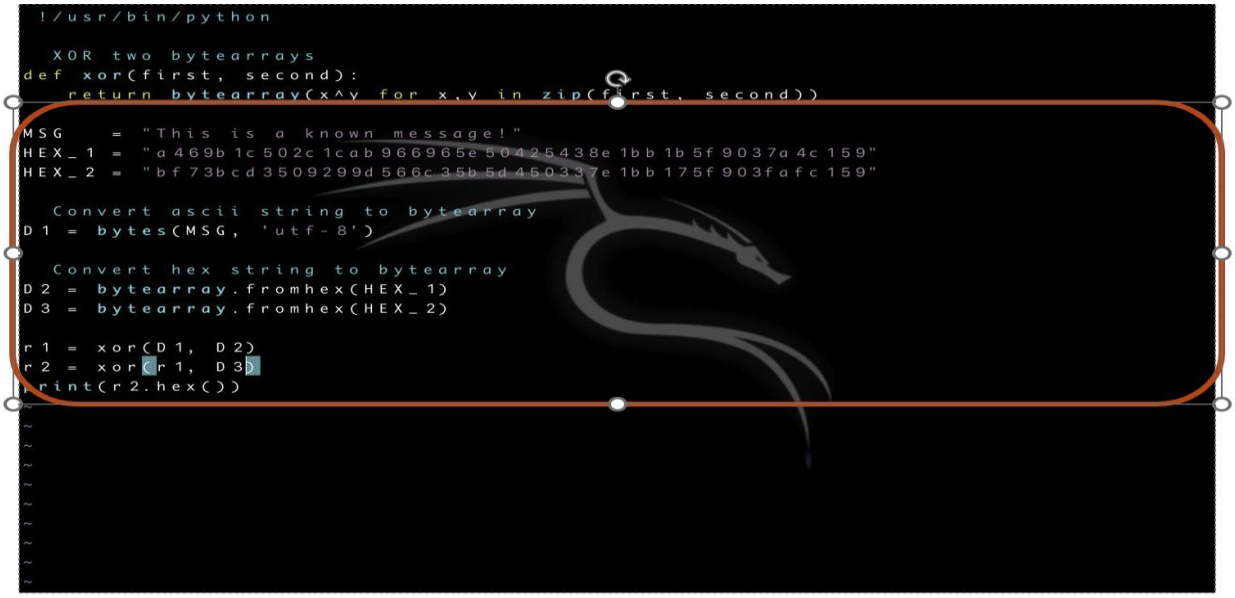
4. What is the known-plaintext attack? What mistake in IV can cause this type of attack?

The known-plaintext attack is a cryptanalysis attack type in which the attacker obtains both the plaintext and its ciphertext. The encryption scheme is not regarded as secure if this can lead to the disclosure of additional sensitive information. According to task 6.2 which is given known ciphertexts (C1, C2) and plaintext (P1) via OFB mode, it can compute to P2 via bitwise ⊕. Because of the same IV, the purpose of C1 ⊕ P1 is to get the key so this key can ⊕ C2 to compute P2.

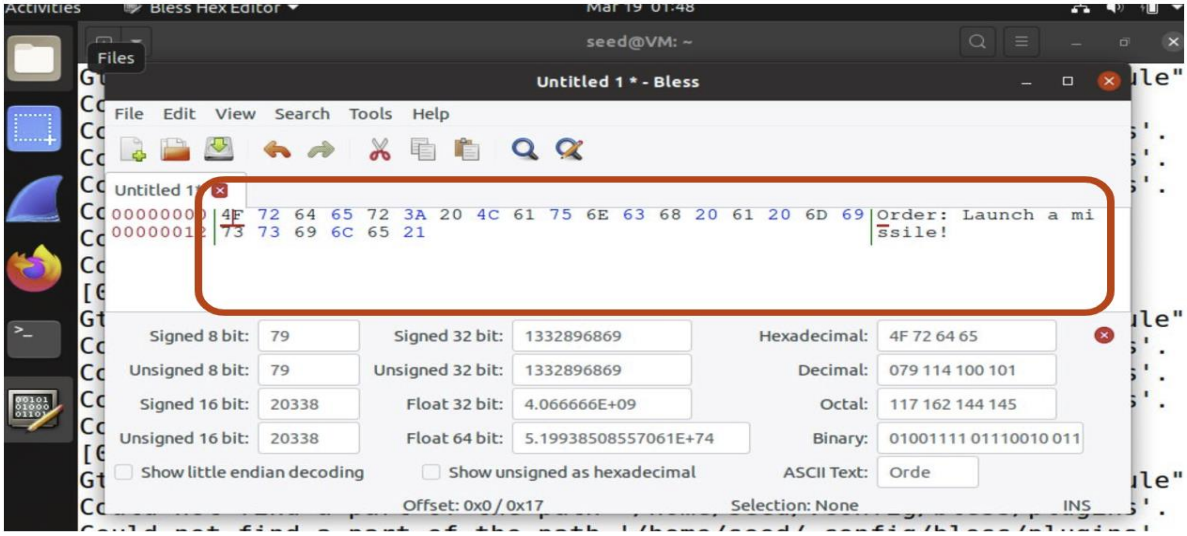
Furthermore, the mistake in IV is that it uses the same IV during the encryption of the plaintext, which is easier to get the key for further computing.

a. Using vim to program sample_code that is included in the lab setup file.

```
[03/19/22]seed@VM:~/.../Files$ vim sample_code.py
[03/19/22]seed@VM:~/.../Files$ python3 sample_code.py
4f726465723a204c61756e63682061206d697373696c6521
[03/19/22]seed@VM:~/.../Files$
```



b. Using Bless convert hexadecimal to decimal, Plaintext P2 is “Order: Launch a missile!”



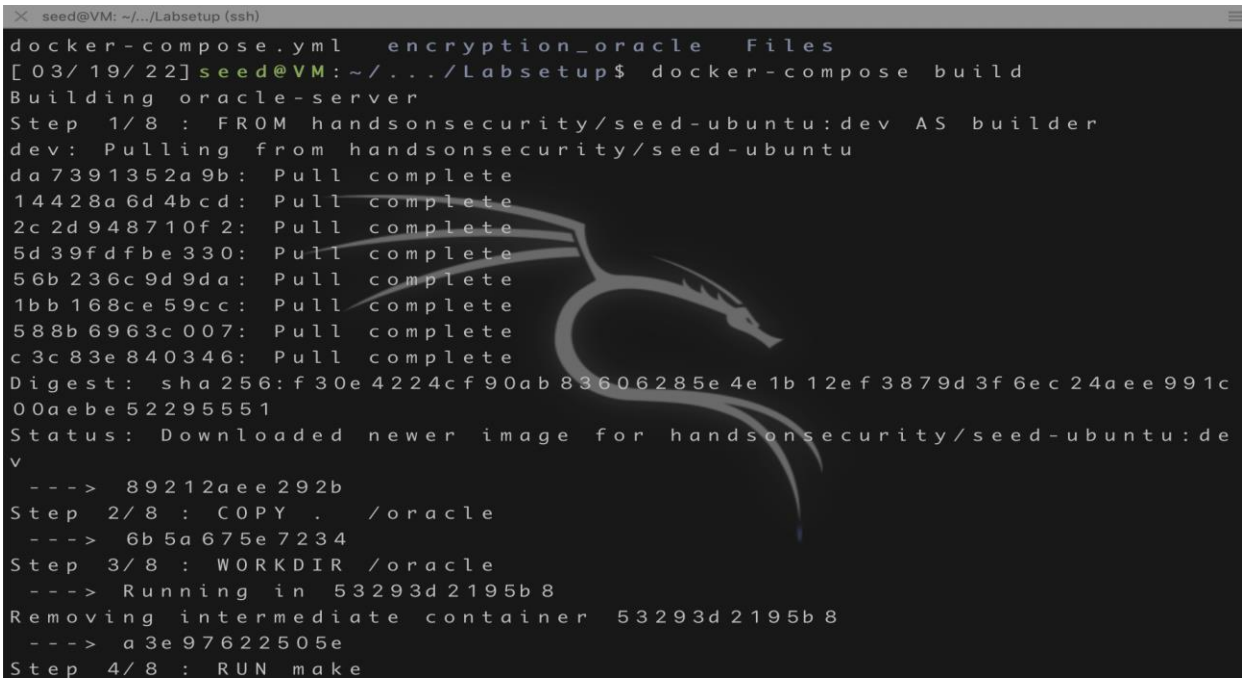
5. How could we compromise a message when we have a ciphertext, IV makes that ciphertext, and the Next IV (as we predict it)?

The biggest failure is being able to guess a message from a ciphertext. The security of encryption means that a plaintext message cannot be guessed any easier by knowing the ciphertext than before. It can forecast the IV if the plaintext is either "yes" or "no," and it needs to estimate which one is from the ciphertext. Then, using a known IV, you can confirm the assumption is "yes" or "no."

In terms of task 6.3 with CBC mode, $Cipher_{Bob} = Encrypt(Plain_{Bob} \oplus IV_{Bob})$. When Bob can predict the next IV, it can compute and choose the plaintext for encryption. If it guesses plaintext $_{Bob}$ is "yes", $Plain_{new} = IV_{new} \oplus IV_{Bob} \oplus$ "yes".

Therefore, $Cipher_{new} = Encrypt(IV_{new} \oplus Plain_{new}) = Encrypt(IV_{new} \oplus (IV_{new} \oplus IV_{Bob} \oplus$ "yes" $)) = Encrypt(IV_{next} \oplus$ "yes"). If the comparison of $Cipher_{Bob}$ and $Cipher_{next}$ is the same, this leads to knowing $Cipher_{next} = Encrypt(IV_{next} \oplus$ "yes"). Otherwise, $Cipher_{next} = Encrypt(IV_{next} \oplus$ "no")

a. Build the encryption_oracle container to use the image



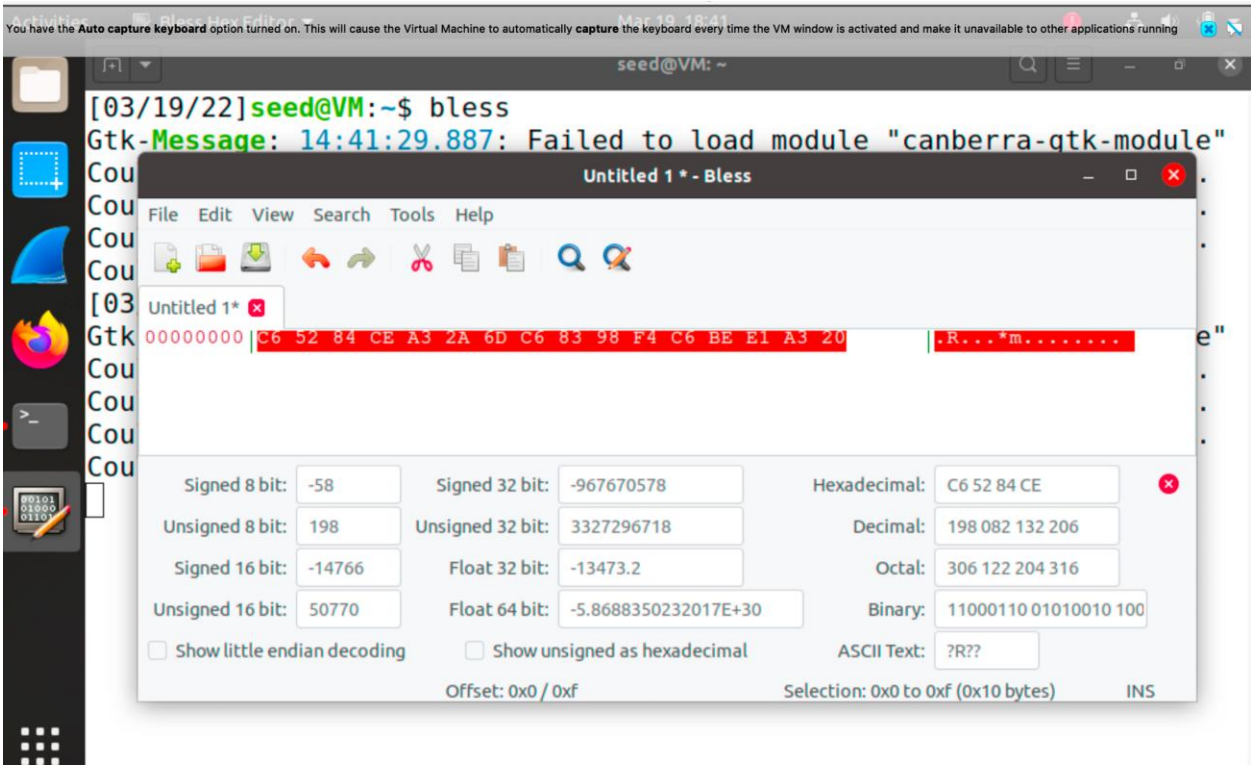
b. Start the oracle service with docker-compose command

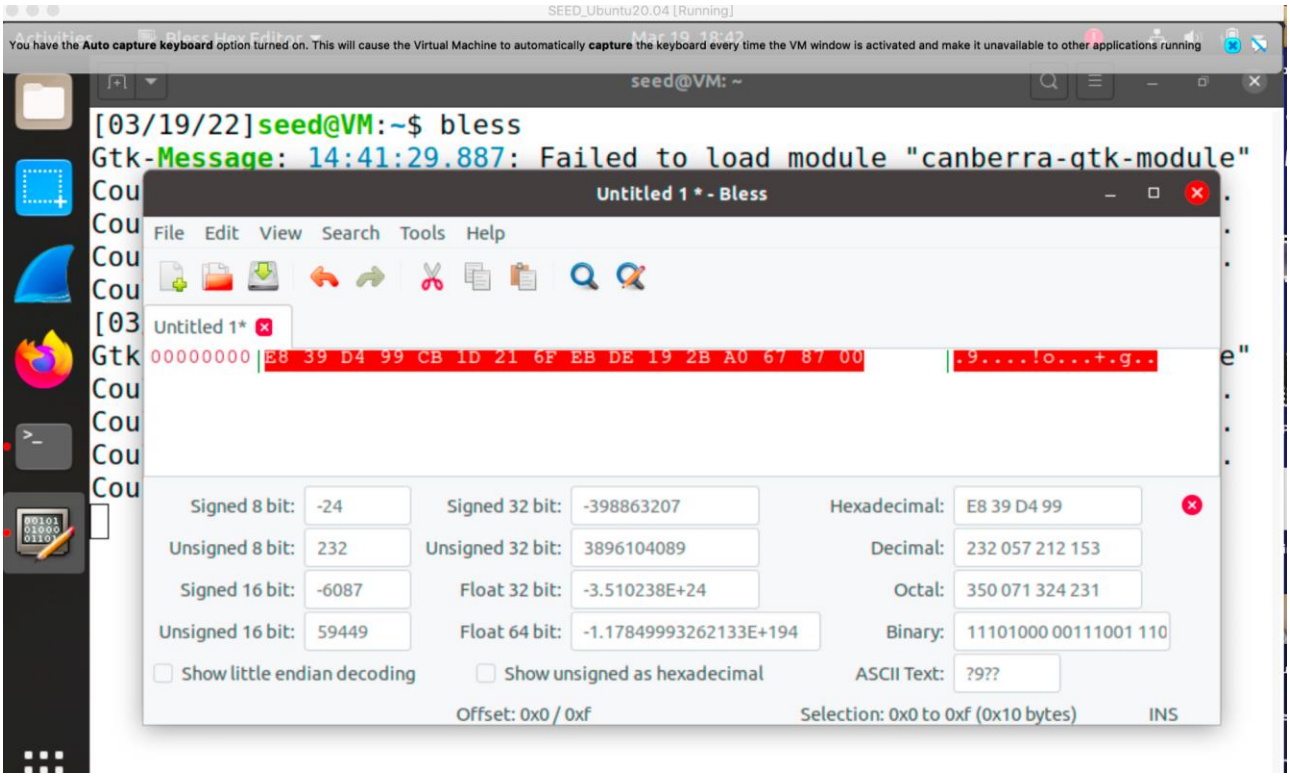
```
[03/19/22]seed@VM:~/.../Labsetup$ docker-compose up
Creating network "net-10.9.0.0" with the default driver
Creating oracle-10.9.0.80 ... done
Attaching to oracle-10.9.0.80
oracle-   . . .    | Server listening on 3000 for known_iv
oracle-   . . .    | Connect to 3000, launching known_iv
oracle-   . . .    | Connect to 3000, launching known_iv
oracle-   . . .    | Connect to 3000, launching known_iv
oracle-   . . .    | Connect to 3000, launching known_iv
oracle-   . . .    | Connect to 3000, launching known_iv
oracle-   . . .    | Connect to 3000, launching known_iv
oracle-   . . .    | Connect to 3000, launching known_iv
```

c. Enter the 8 bytes of plaintext and it will have some padding space to 16 bytes of ciphertext

```
Ray's MackbookPro Terminal
| 17% | 6.5 GB |
seed@VM: ~/.../Labsetup (ssh)
[03/19/22]seed@VM:~/.../Labsetup$ nc 10.9.0.80 3000
Bob's secret message is either "Yes" or "No", without quotations.
Bob's ciphertex: e839d499cb1d216febde192ba0678700
The IV used    : fe8eb66291473491c3885d120d434630

Next IV        : a837b0a791473491c3885d120d434630
Your plaintext : 11223344aabbccdd
Your ciphertext: c65284cea32a6dc68398f4c6bee1a320

Next IV        : af5f27a991473491c3885d120d434630
Your plaintext :
```

d. Check with the difference between the original ciphertext and the next ciphertext encrypting with the next IV via bless hex editor.


You have the Auto capture keyboard option turned on. This will cause the Virtual Machine to automatically capture the keyboard every time the VM window is activated and make it unavailable to other applications running
seed@VM: ~
[03/19/22]seed@VM:~$ bless
Gtk-Message: 14:41:29.887: Failed to load module "canberra-gtk-module"
Untitled 1 * - Bless
File Edit View Search Tools Help
Untitled 1*
00000000 C6 52 84 CE A3 2A 6D C6 83 98 F4 C6 BE E1 A3 20 .R...*m.........
Signed 8 bit: -58
Signed 32 bit: -967670578
Hexadecimal: C6 52 84 CE
Unsigned 8 bit: 198
Unsigned 32 bit: 3327296718
Decimal: 198 082 132 206
Signed 16 bit: -14766
Float 32 bit: -13473.2
Octal: 306 122 204 316
Unsigned 16 bit: 50770
Float 64 bit: -5.8688350232017E+30
Binary: 11000110 01010010 100
Show little endian decoding
Show unsigned as hexadecimal
ASCII Text: ?R??
Offset: 0x0 / 0xf
Selection: 0x0 to 0xf (0x10 bytes)
INS


SEED_Ubuntu20.04 [Running]
You have the Auto capture keyboard option turned on. This will cause the Virtual Machine to automatically capture the keyboard every time the VM window is activated and make it unavailable to other applications running
seed@VM: ~
[03/19/22]seed@VM:~$ bless
Gtk-Message: 14:41:29.887: Failed to load module "canberra-gtk-module"
Untitled 1 * - Bless
File Edit View Search Tools Help
Untitled 1*
00000000 E8 39 D4 99 CB 1D 21 6F EB DE 19 2B A0 67 87 00 .9....!o...+.g..
Signed 8 bit: -24
Signed 32 bit: -398863207
Hexadecimal: E8 39 D4 99
Unsigned 8 bit: 232
Unsigned 32 bit: 3896104089
Decimal: 232 057 212 153
Signed 16 bit: -6087
Float 32 bit: -3.510238E+24
Octal: 350 071 324 231
Unsigned 16 bit: 59449
Float 64 bit: -1.17849993262133E+194
Binary: 11101000 00111001 110
Show little endian decoding
Show unsigned as hexadecimal
ASCII Text: ?9??
Offset: 0x0 / 0xf
Selection: 0x0 to 0xf (0x10 bytes)
INS

Task 7: Programming using the Crypto Library:

1. If you are given plaintext and ciphertext, how can you find the key that is used for encryption when you know

a. The AES-128-CBC is being used for encryption

b. The key is an English word shorter than 16 characters

If it needs to get the encryption key from given information encrypting with AES-128-CBC, the exception is when the keyspace is small enough to allow for a brute force search. The brute-force attack could achieve this goal in terms of the words.txt that is included in the Labsetup.zip file. and this could be the case if the key is obtained from a sentence that is not chosen securely.

With the given information as below, our team writes the pseudocode (C language) which is possible to get the key and also implement how to find the key via python language.
The plaintext is = This is a top secret.
The ciphertext is = 764aa26b55a4da654df6b19e4bce00f4ed05e09346fb0e762583cb7da2ac93a2
The IV is = aabbccddeeff00998877665544332211

I. Pseudocode(C language):

#include openssl/aes library
#include stdlib library
#include stdio library
#include string library
#include assert library // Verify the program's assumptions and return boolean True/False
#define global variables charMaxLength //This is used to allocate the buffer size via malloc function

Declare string to hexadecimal function(string parameter):

Declare two variables, one value is null and another one of value is equal to the length of string parameter

Using assert function which takes the remainder from the length of string parameter divided by two and this is equal to zero.

Using malloc function allocates the memory to the variable that value is null
For loop with the counter in range the length of the string:
read the formatted input from the string to the variable
return the allocated variable

Declare buffer padding function(buffer size, plaintext size, padding size):
Declare a padding size which calculates from AES_Block_Size and plaintext size
Declare a counter
Declare a null variable
Using malloc function allocates the memory to the null variable
If (the padding size is not zero) then
For loop with the counter in range of accumulation padding size and plaintext size:
The allocated null variable size is equal to padding size

return the allocated variable

Declare print buffer function(buffer size, padding size):
Declare an initial variable
For loop in range of padding size:
print buffer content

Declare encrypt buffer function(after_Padding size, encrypt buffer size, padding size, key buffer):
Call string to hexadecimal function(key buffer)
Call string to hexadecimal function("aabbccddeeff00998877665544332211")
using AES_set_encrypt_key function with 128 bits, which is included in openssl/aes.h
using AES_cbc_encrypt function, which is included in openssl/aes.h
free memory

Declare main function():
Ciphertext"764aa26b55a4da654df6b19e4bce00f4ed05e09346fb0e762583cb7da2ac93a2"
Declare file pointer P, which points to open words.txt and read only

Define buffer size with global variables charMaxLength

While (P is true)

While (comparison with ciphertext is false)

Get the file string with the buffer size of global variables charMaxLength

Declare key buffer with malloc function

While (less than buffer length)

key buffer accumulates with file buffer

Declare plaintext buffer with malloc function

Copy memory of "This is a top secret." to plaintext buffer

Call buffer padding function (plaintext buffer, initial padding size)

Declare encrypt buffer with malloc function

Call encrypt buffer function(after_buffer_Padding size, encrypt buffer, padding size, key buffer)

Call print buffer function(encrypt buffer, padding size)

print encrypt key

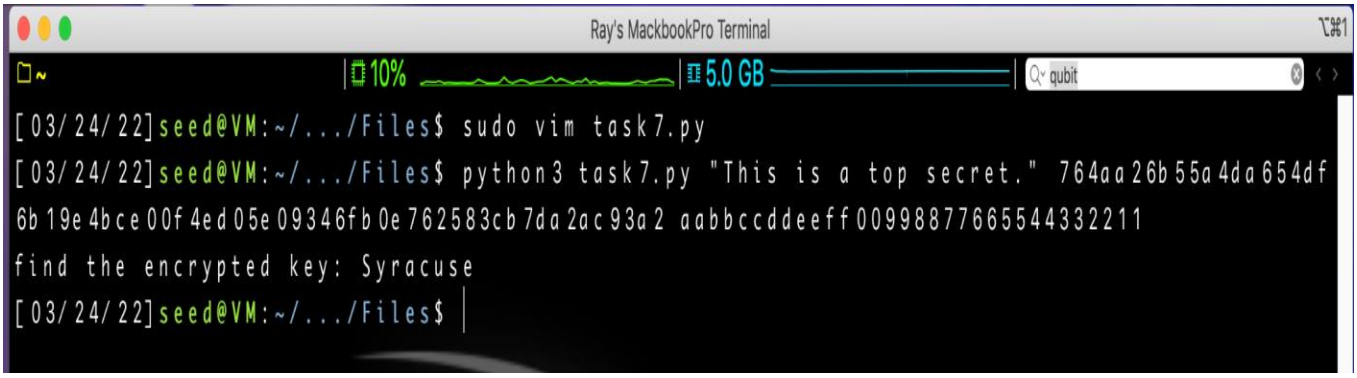
free memory

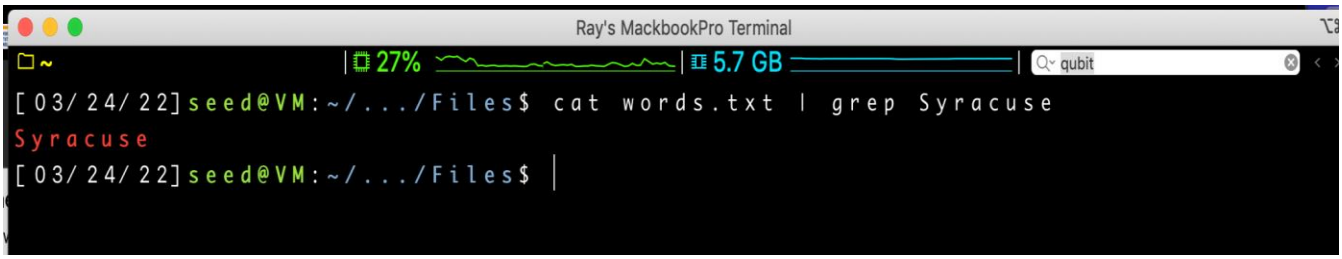
File close (P)

return 0

II. Python language

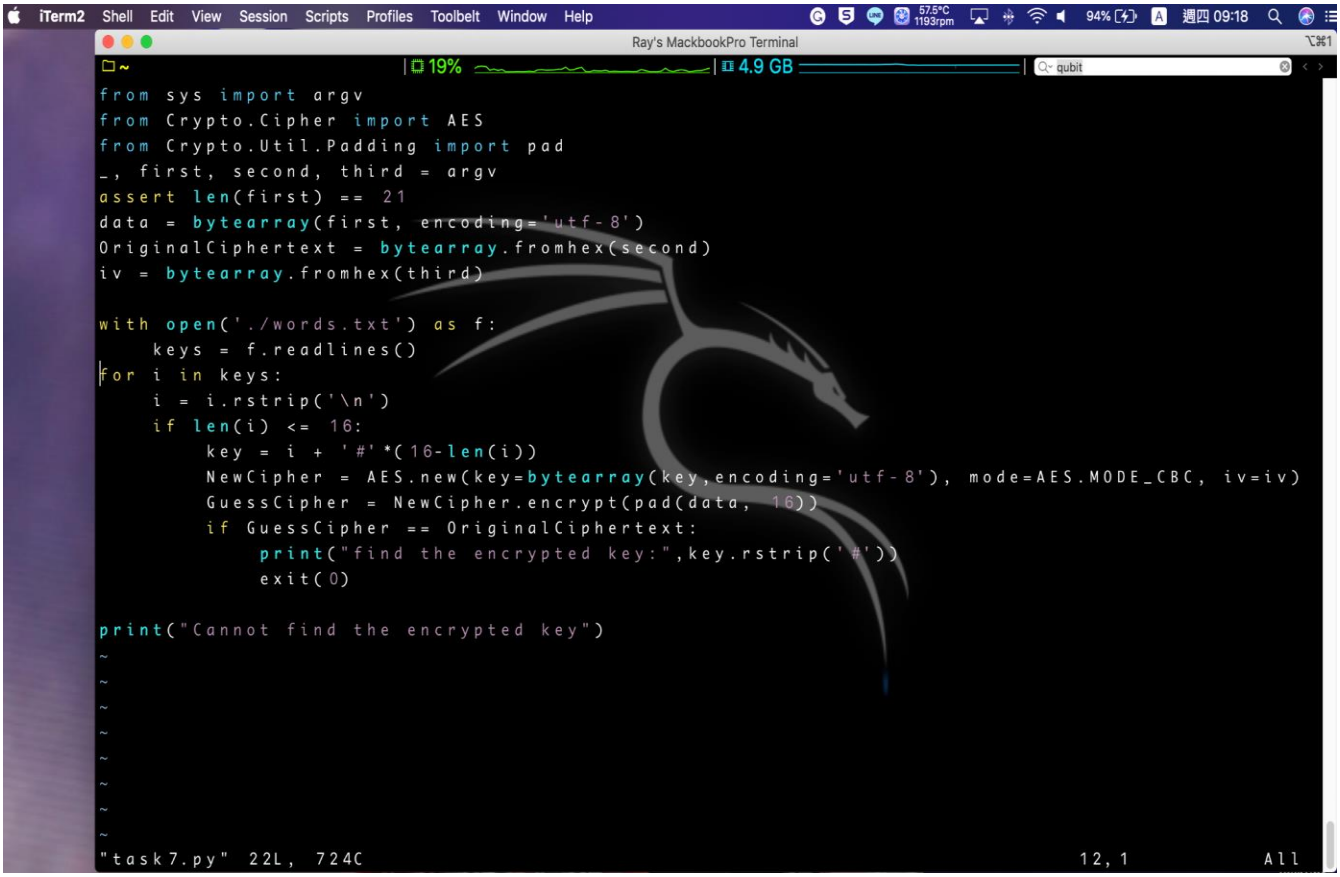
If the given ciphertext, plaintext, IV are the program's argument, the program can find the encrypted key which is **Syracuse**. And, this word also is in the words.txt





Task7 Python Code:

Must import AES and padding function from Crypto library, and then implement padding scheme on key retrieved from words.txt which need to have 16 lengths. Therefore, encrypt the given iv, given plaintext and the padding key to generate the NewCipher compared to the OriginalCipher in order to find the correct encrypted key.



Explanation:

The whole concept of the pseudocode (C language) and python program is that using each string of the words.txt file as the encrypted key, and then encrypting with the given plaintext and IV to generate ciphertext compared to original ciphertext whether is the same or not. If it is the same, the program finds the encrypted key.

IV. REFERENCES

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