Applied Cryptography Lab-05 Manual

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Lab: 4

***Note**: The demo showed in the video for this lab has been performed on Ubuntu 22.04 running on wsl2. So far, there have been no changes noted between the execution of this lab on wsl and execution on the seedlabs Ubuntu 20.04 virtualbox vm.*
Therefore, despite the differences in environment, all tasks in the lab should run smoothly.

Task 1: A Complete Example of BIGNUM

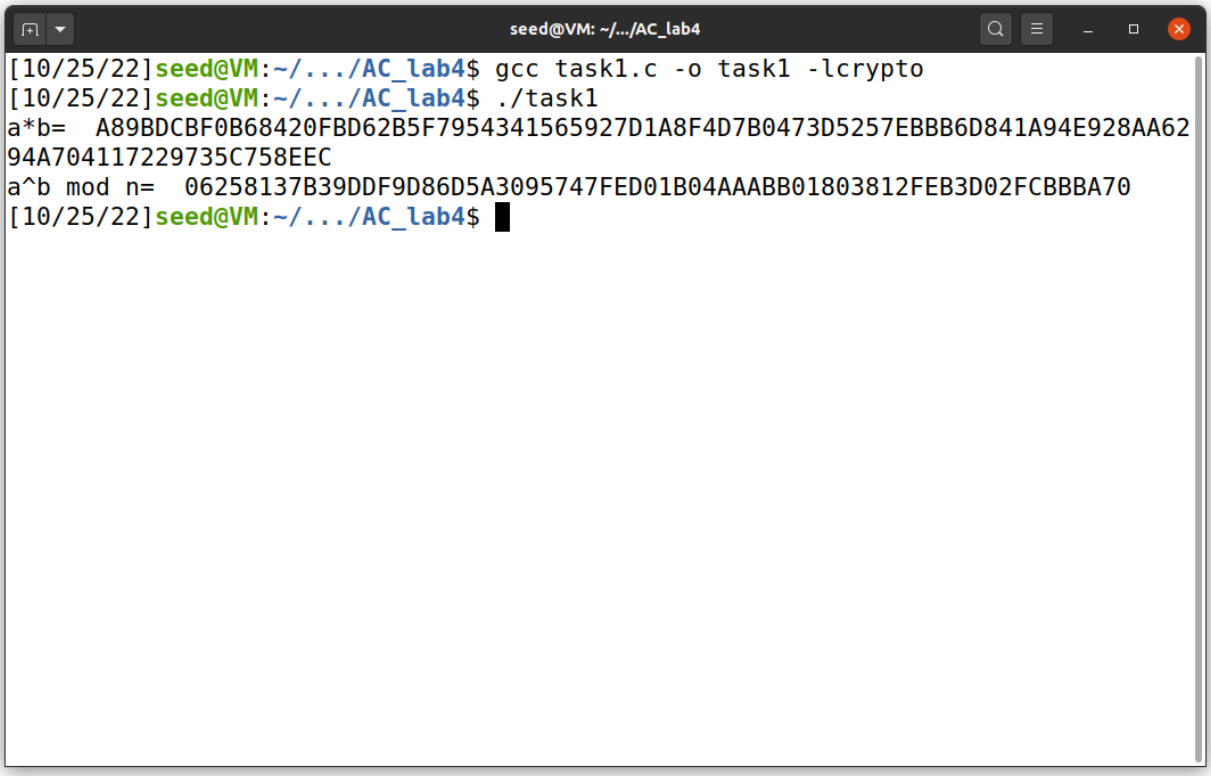
The program below shows a complete example of BIGNUM. This program uses three BIGNUM variables, a, b, and n; and then compute a * b and (a b mod n)

Code

```
#include <stdio.h>
#include <openssl/bn.h>
#define NBITS 256
void printBN(char*msg, BIGNUM*a) {
    /* Use BN_bn2hex(a) for hex string
       Use BN_bn2dec(a) for decimal string*/
    char* number_str = BN_bn2hex(a);
    printf("%s %s\n",msg,number_str);
    OPENSSL_free(number_str);
}
int main() {
    BN_CTX *ctx = BN_CTX_new();
    BIGNUM *a = BN_new();
    BIGNUM *b = BN_new();
    BIGNUM *n = BN_new();
    BIGNUM *res = BN_new();
    // Initialize
    BN_generate_prime_ex(a,NBITS,1,NULL,NULL,NULL);
    BN_dec2bn(&b,"27348946379683850184859276946719436926 8");
    BN_rand(n,NBITS,0,0);
    // res = a*b
    BN_mul(res,a,b,ctx);
    printBN("a*b=",res);
    // res = a^b mod n
    BN_mod_exp(res,a,b,n,ctx);
    printBN("a^b mod n=",res);
    return 0;
}
```

Commands

```
$ gcc task1.c -o task1 -lcrypto
$ ./task1
```



We can see the result of multiplication of 2 large numbers in the first row of the output and we can see the modulus of that result by a number 'n' in the second row of the output in the terminal.

Task 2: Deriving the Private Key

The objective of this task is to derive private key. Given are the hexadecimal values of p, q, e, and public key pair (e,n)

p = F7E75FDC469067FFDC4E847C51F452DF

q = E85CED54AF57E53E092113E62F436F4F

e = 0D88C3

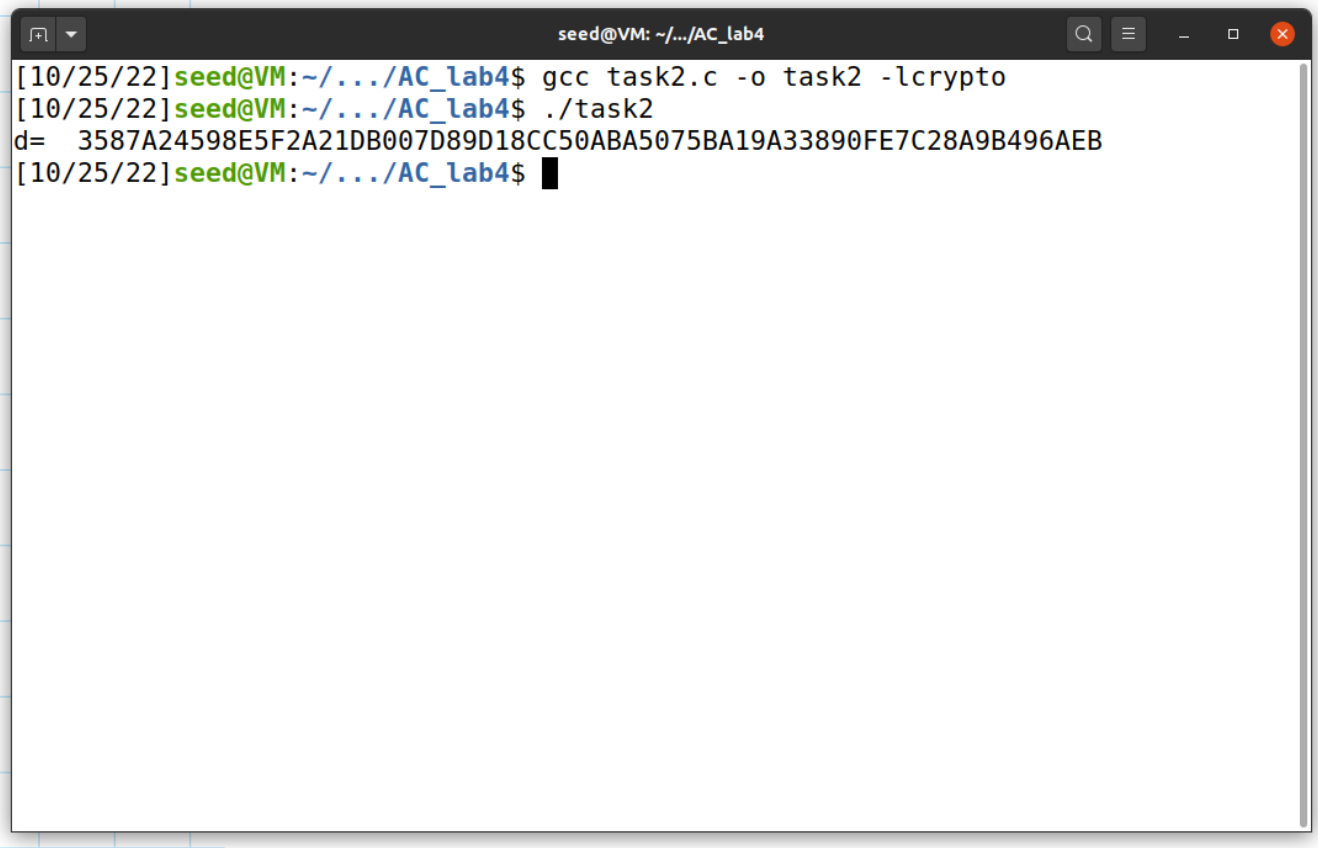
Code

```
#include <stdio.h>
#include <openssl/bn.h>
#define NBITS 256
void printBN(char*msg, BIGNUM*a) {
    /* Use BN_bn2hex(a) for hex string
        Use BN_bn2dec(a) for decimal string*/
    char* number_str = BN_bn2hex(a);
    printf("%s %s\n",msg,number_str);
    OPENSSL_free(number_str);
}
int main() {
    BN_CTX *ctx = BN_CTX_new();
    BIGNUM *p = BN_new();
    BIGNUM *q = BN_new();
    BIGNUM *e = BN_new();
    BIGNUM *d = BN_new();
    BIGNUM *res1 = BN_new();
```

```
    BIGNUM *res2 = BN_new();
    BIGNUM *res3 = BN_new();
    BIGNUM *one = BN_new();
    // Initialize
    BN_hex2bn(&p,"F7E75FDC469067FFDC4E847C51F452DF");
    BN_hex2bn(&q,"E85CED54AF57E53E092113E62F436F4F");
    BN_hex2bn(&e,"0D88C3");
    BN_hex2bn(&one,"1");
    BN_sub(res1,p,one);
    BN_sub(res2,q,one);
    BN_mul(res3,res1,res2,ctx);
    BN_mod_inverse(d,e,res3,ctx);
    printBN("d=",d);
    return 0;
}
```

Commands

```
$ gcc task2.c -o  task2 -lcrypto
$ ./task2
```



The decryption key found is mentioned in the above screenshot by Elgamal method.
First we calculate Euler's totient (p-1)*(q-1)
Then we find mod inverse to find the decryption key to find d

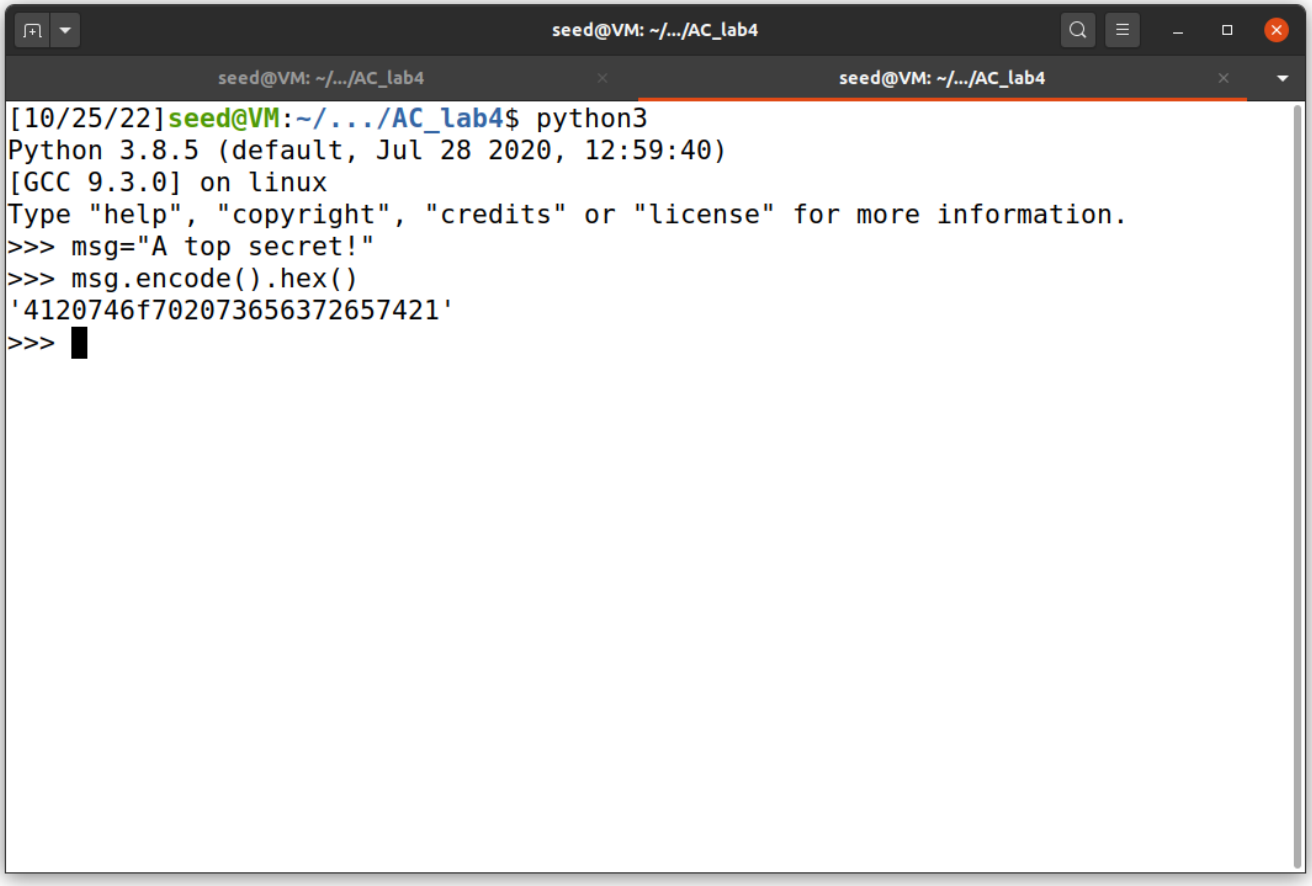
Task 3: Encrypting a Message

The objective of this task is to encrypt a given message. Given are the hexadecimal values of n, e, M (you can use whatever message you want). The value of "d" is also given to verify the result.

Step 1

Convert the ASCII String message to a hex string

```
python3 -c "print('A top secret!'.encode().hex())"
```



We are finding the hexadecimal form of the text messge and inserting it in the code as the text message.

Give your observation with a screenshot

Step 2

Execute the below program to encrypt the message M and verify it by decrypting it.

Code

```c
#include <stdio.h>
#include <openssl/bn.h>
#define NBITS 256
void printBN(char*msg, BIGNUM*a) {
    /* Use BN_bn2hex(a) for hex string
        Use BN_bn2dec(a) for decimal string*/
    char* number_str = BN_bn2hex(a);
    printf("%s %s\n",msg,number_str);
    OPENSSL_free(number_str);
}
int main() {
    BN_CTX *ctx = BN_CTX_new();
    BIGNUM *m = BN_new();
    BIGNUM *e = BN_new();
    BIGNUM *n = BN_new();
    BIGNUM *d = BN_new();
    BIGNUM *enc = BN_new();
```

n = DCBFFE3E51F62E09CE7032E2677A78946A849DC4CDDE3A4D0CB81629242FB1A5

e = 010001 (This hex value equal to decimal 65537)

M = A top secret!

d = 74D806F9F3A62BAE331FFE3F0A68AFE35B3D2E4794148AACBC26AA381CD7D30D

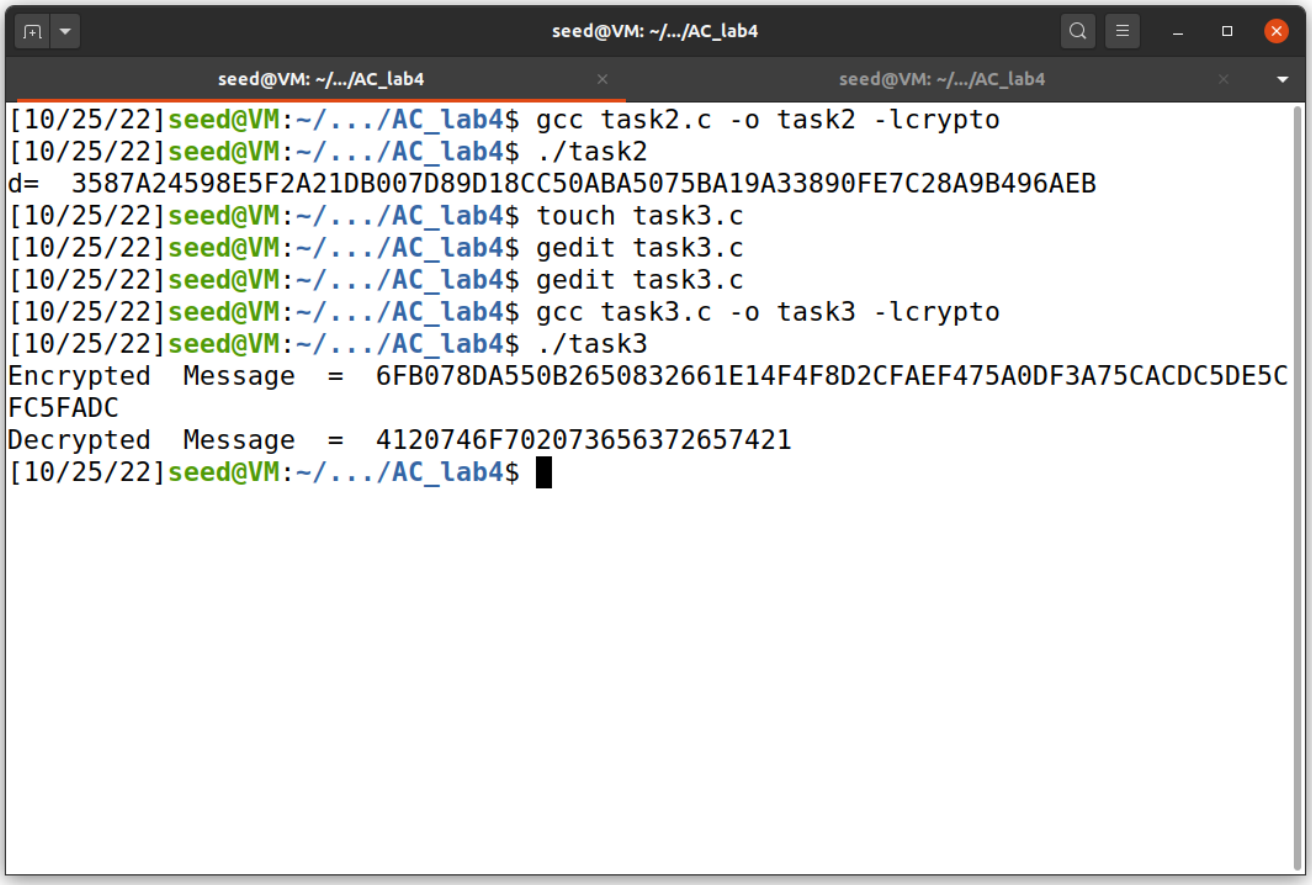
```c
                                                    step 1 >>");
    BIGNUM *dec = BN_new();

    // Initialize
    BN_hex2bn(&m,"<< Enter the message in hex, obtained in
    BN_hex2bn(&e,"010001");
    BN_hex2bn(&n,"DCBFFE3E51F62E09CE7032E2677A78946A849DC4CDDE3A4D0CB81629242FB1A5");
    BN_hex2bn(&d,"74D806F9F3A62BAE331FFE3F0A68AFE35B3D2E4794148AACBC26AA381CD7D30D");
    // Encryption
    BN_mod_exp(enc,m,e,n,ctx);
    printBN("Encrypted Message =",enc);
    // Decryption
    BN_mod_exp(dec,enc,d,n,ctx);
    printBN("Decrypted Message =",dec);
    return 0;
```

}

Commands

```
$ gcc task3.c -o   task3 -lcrypto
$ ./task3
```

First we are doing
encryption: enc=m^e mod n
Then we are doing
decryption:dec=enc^d mod n



We are getting the same text message when we decrypt the ciphertext.

Task 4: Decrypting a Message

The objective of this task is to decrypt a given ciphertext. given are the hexadecimal values of n, e, d from the above task

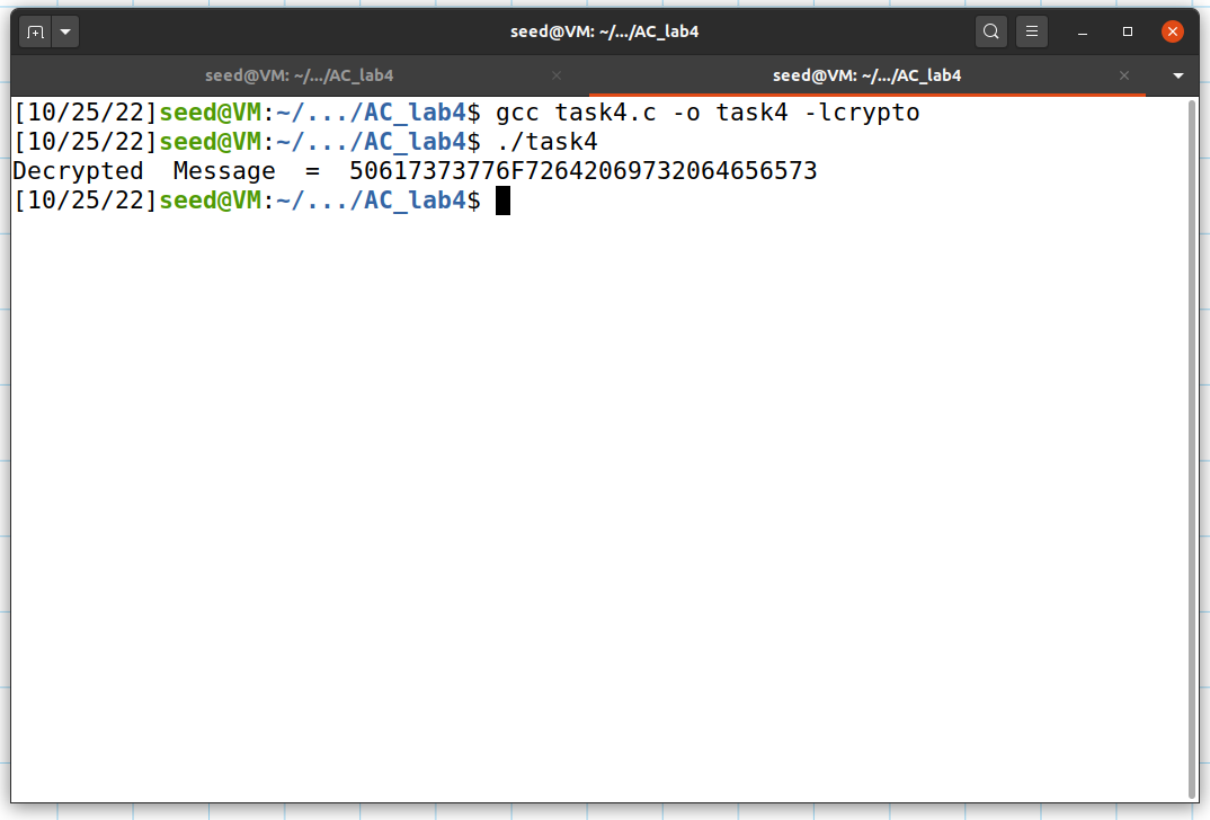
C =
8C0F971DF2F3672B28811407E2DABBE1DA0FEBBBDFC7DCB67396567E
A1E2493F

Code

```
#include <stdio.h>
#include <openssl/bn.h>
#define NBITS 256
void printBN(char*msg, BIGNUM*a) {
    /* Use BN_bn2hex(a) for hex string
        Use BN_bn2dec(a) for decimal string*/
    char* number_str = BN_bn2hex(a);
    printf("%s %s\n",msg,number_str);
    OPENSSL_free(number_str);
}
int main() {
    BN_CTX *ctx = BN_CTX_new();
    BIGNUM *m = BN_new();
    BIGNUM *e = BN_new();
    BIGNUM *n = BN_new();
    BIGNUM *d = BN_new();
    BIGNUM *enc = BN_new();
    BIGNUM *dec = BN_new();
    // Initialize
    BN_hex2bn(&n,"DCBFFE3E51F62E09CE7032E2677A78946A849DC4CDDE3A4D0CB81629242FB1A5");
    BN_hex2bn(&d,"74D806F9F3A62BAE331FFE3F0A68AFE35B3D2E4794148AACBC26AA381CD7D30D");
    BN_hex2bn(&enc,"8C0F971DF2F3672B28811407E2DABBE1DA0FEBBBDFC7DCB67396567EA1E2493F"
);
    // Decryption
    BN_mod_exp(dec,enc,d,n,ctx);
    printBN("Decrypted Message =",dec);
    return 0;
}
```

Commands

```
$ gcc task4.c -o  task4 -lcrypto
$ ./task4
```



We are finding the message given the ciphertext and decryption key

```
>>> bytes.fromhex('50617373776F72642069732064656573')
b'Password is dees'
>>>
```

When we convert the plaintext to bytes we get the above text as the message text.

Task 5: Signing a Message

The objective of this task is to generate a signature for the following message. Use the public/private key set from task3

M= I owe you $2000

Step 1

Generate hex for M

```
python3 -c "print('I owe you $2000'.encode().hex())"
```

Step 2

Execute the e following program to generate signature of the given message. Using the signing algorithm M^d mod n

Code

```
#include <stdio.h>
#include <openssl/bn.h>
#define NBITS 256
void printBN(char*msg, BIGNUM*a) {
    /* Use BN_bn2hex(a) for hex string
        Use BN_bn2dec(a) for decimal string*/
    char* number_str = BN_bn2hex(a);
    printf("%s %s\n",msg,number_str);
    OPENSSL_free(number_str);
}
int main() {
    BN_CTX *ctx = BN_CTX_new();
    BIGNUM *m = BN_new();
    BIGNUM *n = BN_new();
    BIGNUM *d = BN_new();
    BIGNUM *sign = BN_new();
    // Initialize
    BN_hex2bn(&m,"<< Hex value of M >>");
    BN_hex2bn(&n,"DCBFFE3E51F62E09CE7032E2677A78946A849DC4CDDE3A4D0CB81629242FB1A5");
    BN_hex2bn(&d,"74D806F9F3A62BAE331FFE3F0A68AFE35B3D2E4794148AACBC26AA381CD7D30D");
    // Signing
    BN_mod_exp(sign,m,d,n,ctx);
    printBN("Sign =",sign);
    return 0;
}
```

Commands

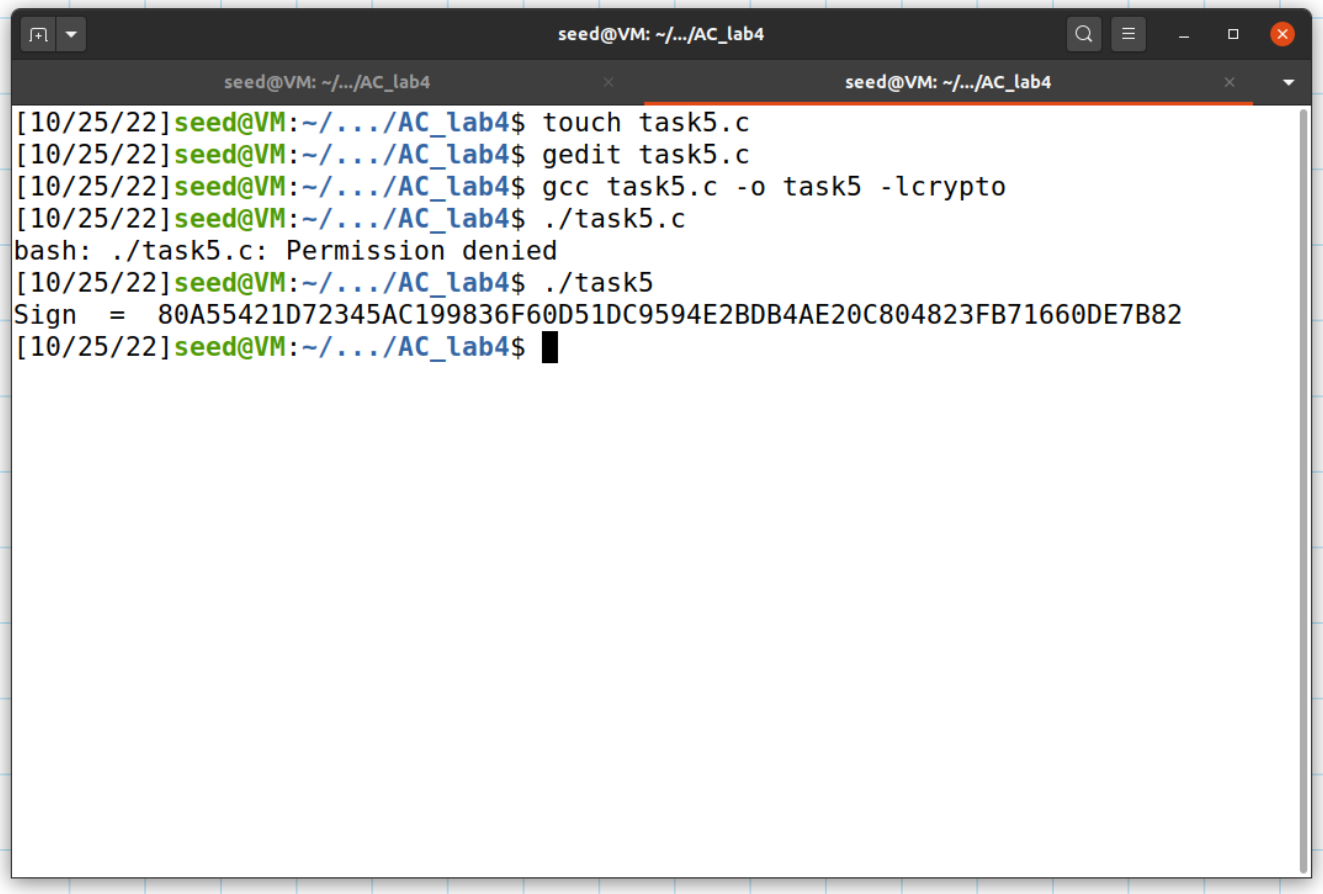
```
$ ./task5
$ gcc task5.c -o
```

Step 3

task5 -lcrypto

Execute steps 1 and 2 for the message "I owe $3000"

```
>>> msg1='I owe you $2000'
>>> msg1.encode().hex()
'49206f776520796f75202432303030'
>>>
```



We are generating the signature of the given plain text
Sign = m^d mod n

Task 6: Verifying a signature

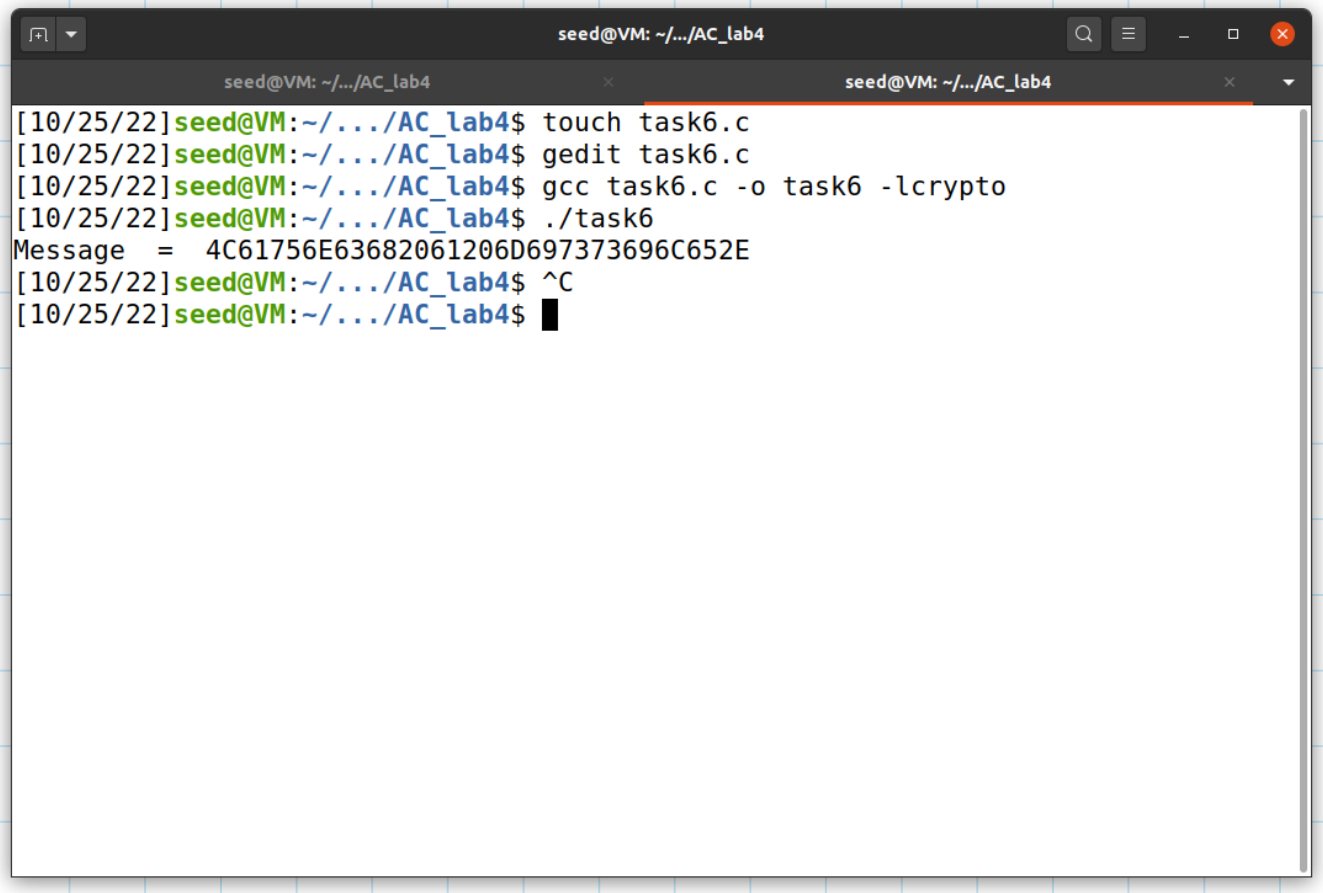
The objective of this task is to verify if the signature received by Bob is Allice's or not. Given are the Message M, signature S, Allice public key e and n.

Code

```
#include <stdio.h>
#include <openssl/bn.h>
#define NBITS 256
void printBN(char*msg, BIGNUM*a) {
    /* Use BN_bn2hex(a) for hex string
        Use BN_bn2dec(a) for decimal string*/
    char* number_str = BN_bn2hex(a);
    printf("%s %s\n",msg,number_str);
    OPENSSL_free(number_str);
}
int main() {
    BN_CTX *ctx = BN_CTX_new();
    BIGNUM *s = BN_new();
    BIGNUM *n = BN_new();
    BIGNUM *e = BN_new();
    BIGNUM *message = BN_new();
    // Initialize
    BN_hex2bn(&s,"643D6F34902D9C7EC90CB0B2BCA36C47FA37165C0005CAB026C0542CBDB6802
F");
    BN_hex2bn(&n,"AE1CD4DC432798D933779FBD46C6E1247F0CF1233595113AA51B450F1811611
5");
    BN_hex2bn(&e,"010001");
    // Signing
    BN_mod_exp(message,s,e,n,ctx);
    printBN("Message =",message);
    return 0;
}
```

Commands

```
$ gcc task6.c -o task6 -lcrypto
$ ./task6
$ python3 -c "print(bytes.fromhex('<< output of
task6 >>'))"
```




```
>>> bytes.fromhex('4C61756E63682061206D697373696C652E')
b'Launch a missile.'
>>>
```

We are getting back the message by using the signature and the by decrypting using public key.

Task 7: Manually Verifying X.509 Certificate

The objective of this task is to verify the signature of a public key certificate from a server and show that the signature matches

To verify that a certificate was signed by a specific certificate authority we need the following details

1. Public key of the certificate authority (issuer).

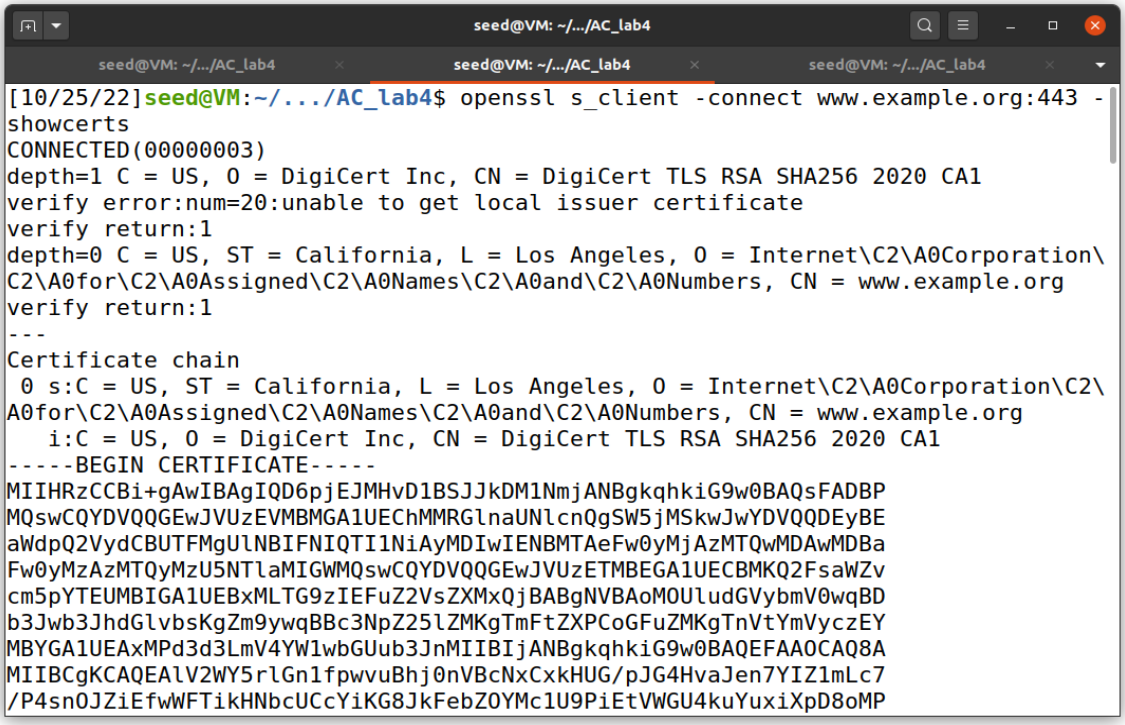
2. signature and algorithm used to generate signature from the server's certificate.

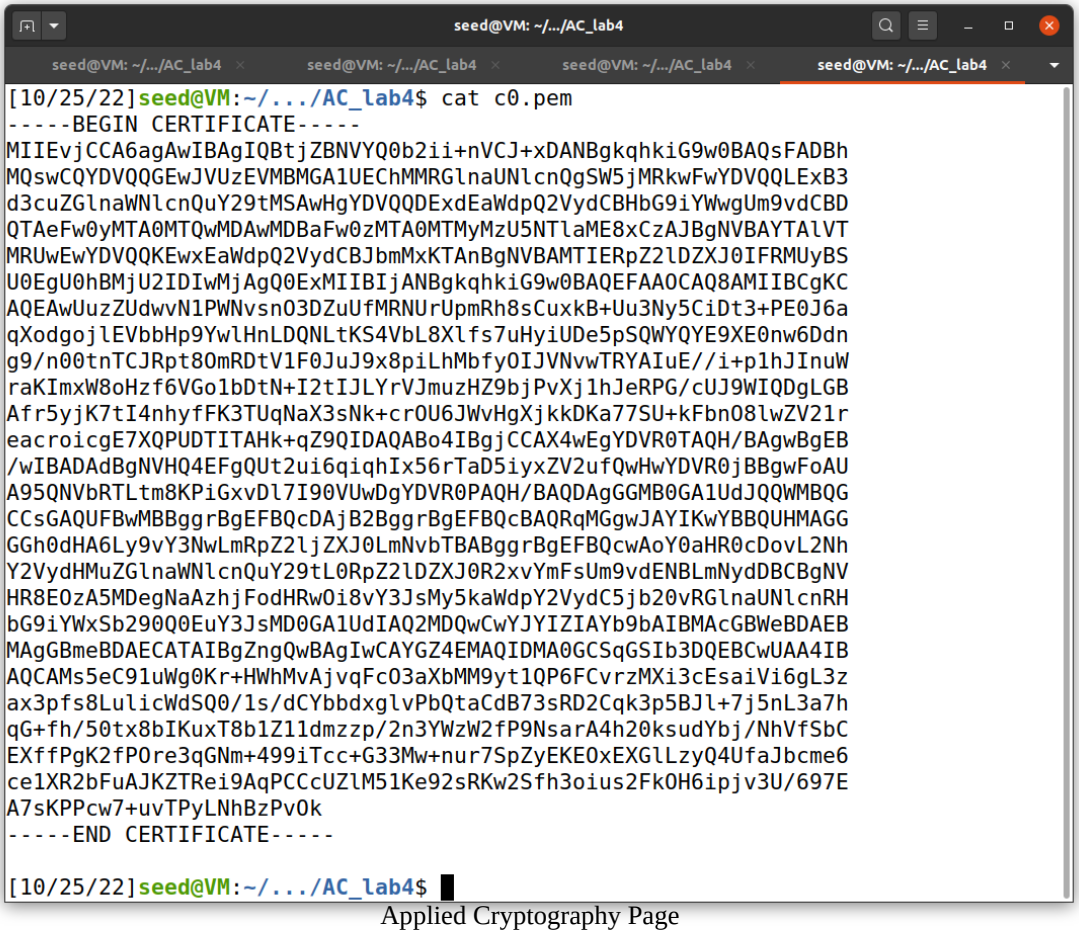
Step 1

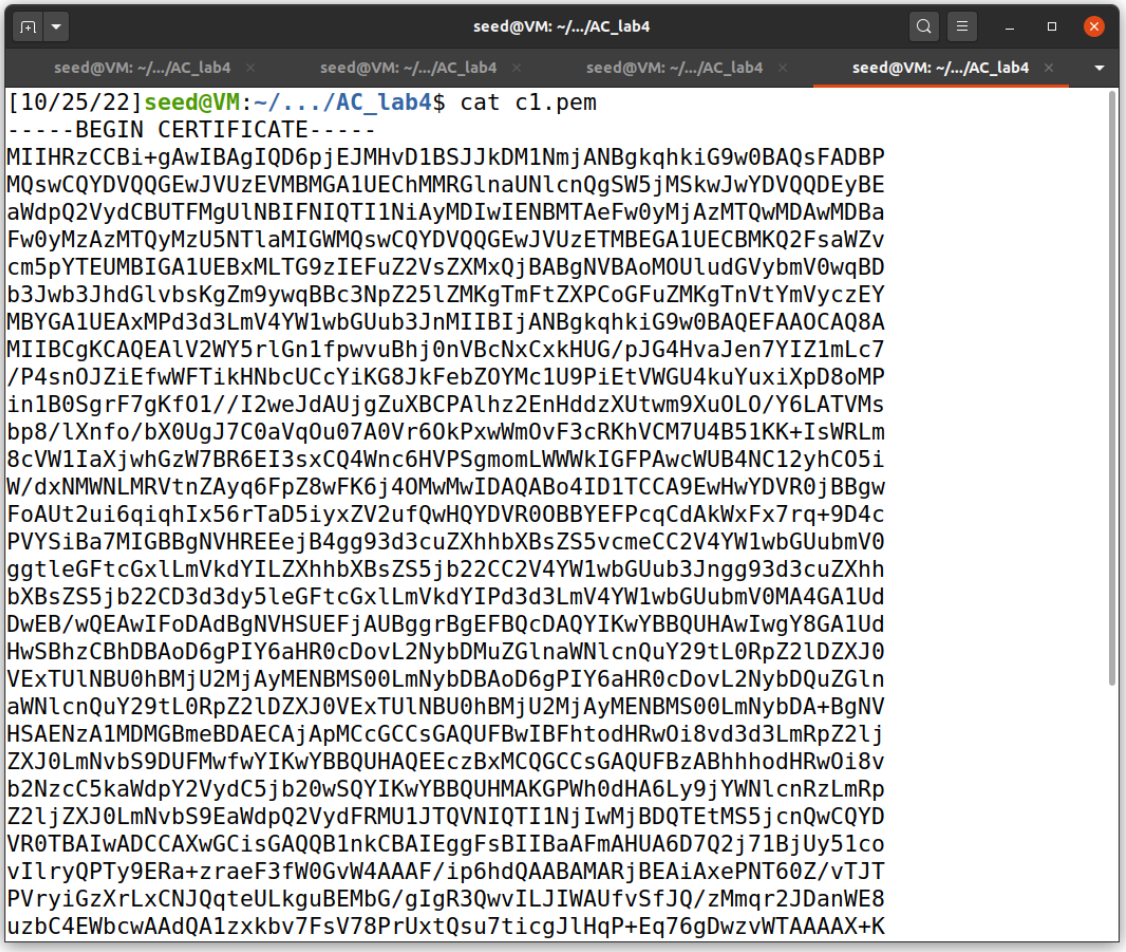
Download the certificate from any website (each student use a different website)

$ openssl s_client -connect www.example.org:443 -showcerts

Copy server certificate to c0.pem file and root certificate of the issuer to c1.pem



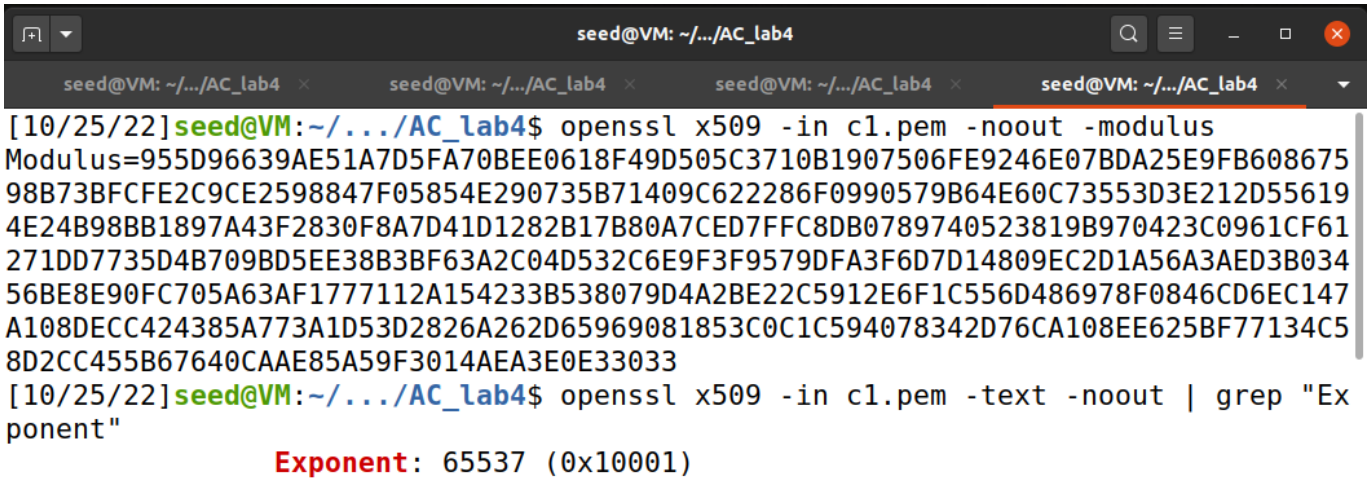




Step 2

Extract the public key (e, n) from the issuer's certificate. Openssl provides commands to extract certain attributes from the x509 certificates. We can extract the value of n using -modulus. There is no specific command to extract e, but we can print out all the fields and can easily find the value of e.

```
$ openssl x509 -in c1.pem -noout -modulus
$ openssl x509 -in c1.pem -text -noout |grep "Exponent"
```



Give your observation with screenshot

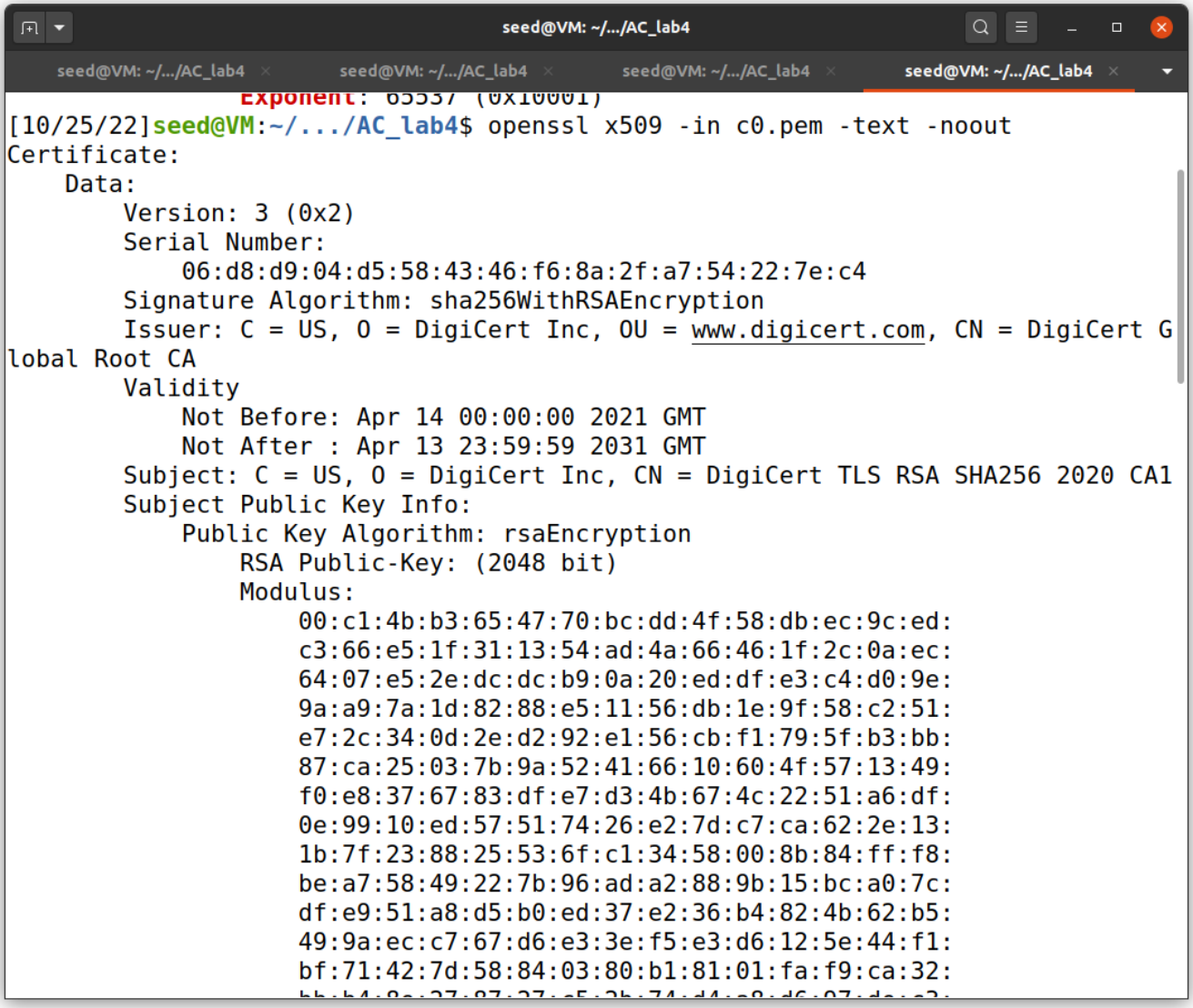
Step 3

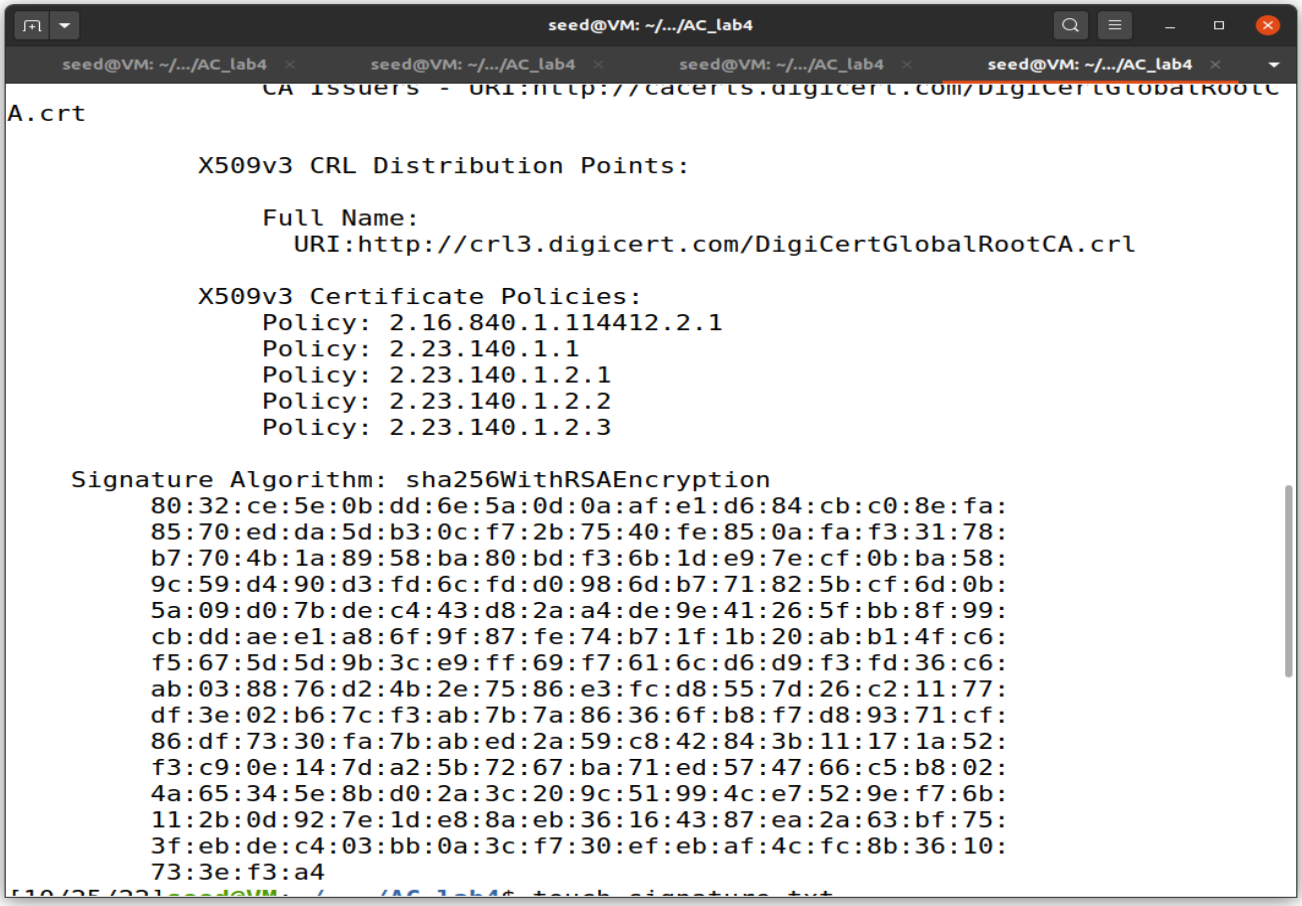
Extract the signature from the server's certificate. There is no specific openssl command to extract the signature field. However, we can print out all the fields and then copy and paste the signature block into a file (note: if the signature algorithm used in the certificate is not based on RSA, find another certificate).

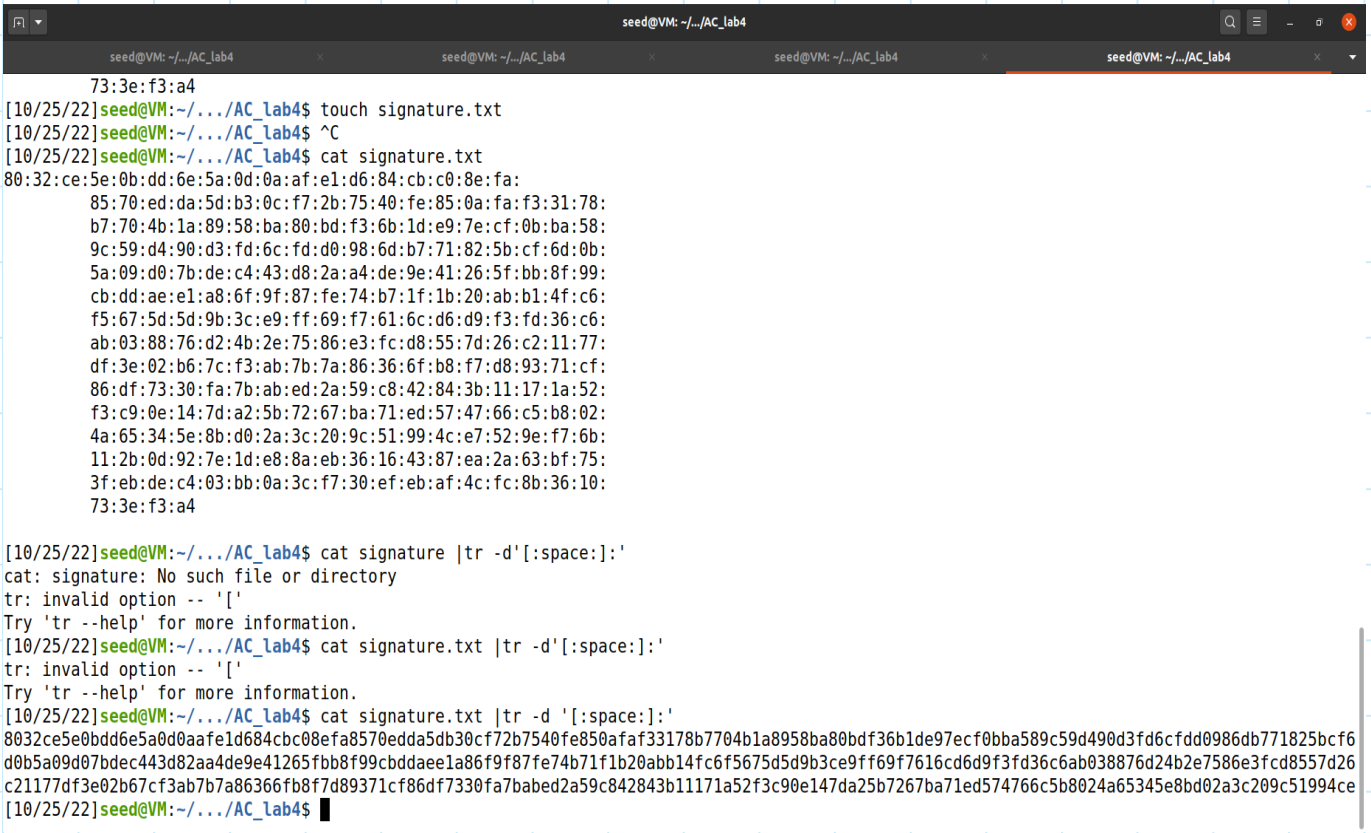
Commands

```
$openssl x509 -in c0.pem -text -noout
//extract only the signature part and paste it in signature file
$ cat signature | tr -d '[:space:]:'
```

Give your observation with screenshot.


seed@VM: ~/.../AC_lab4
seed@VM: ~/.../AC_lab4
seed@VM: ~/.../AC_lab4
seed@VM: ~/.../AC_lab4
seed@VM: ~/.../AC_lab4
Exponent: 65537 (0x10001)
[10/25/22]seed@VM:~/.../AC_lab4$ openssl x509 -in c0.pem -text -noout
Certificate:
Data:
Version: 3 (0x2)
Serial Number:
06:d8:d9:04:d5:58:43:46:f6:8a:2f:a7:54:22:7e:c4
Signature Algorithm: sha256WithRSAEncryption
Issuer: C = US, O = DigiCert Inc, OU = www.digicert.com, CN = DigiCert G
lobal Root CA
Validity
Not Before: Apr 14 00:00:00 2021 GMT
Not After : Apr 13 23:59:59 2031 GMT
Subject: C = US, O = DigiCert Inc, CN = DigiCert TLS RSA SHA256 2020 CA1
Subject Public Key Info:
Public Key Algorithm: rsaEncryption
RSA Public-Key: (2048 bit)
Modulus:
00:c1:4b:b3:65:47:70:bc:dd:4f:58:db:ec:9c:ed:
c3:66:e5:1f:31:13:54:ad:4a:66:46:1f:2c:0a:ec:
64:07:e5:2e:dc:dc:b9:0a:20:ed:df:e3:c4:d0:9e:
9a:a9:7a:1d:82:88:e5:11:56:db:1e:9f:58:c2:51:
e7:2c:34:0d:2e:d2:92:e1:56:cb:f1:79:5f:b3:bb:
87:ca:25:03:7b:9a:52:41:66:10:60:4f:57:13:49:
f0:e8:37:67:83:df:e7:d3:4b:67:4c:22:51:a6:df:
0e:99:10:ed:57:51:74:26:e2:7d:c7:ca:62:2e:13:
1b:7f:23:88:25:53:6f:c1:34:58:00:8b:84:ff:f8:
be:a7:58:49:22:7b:96:ad:a2:88:9b:15:bc:a0:7c:
df:e9:51:a8:d5:b0:ed:37:e2:36:b4:82:4b:62:b5:
49:9a:ec:c7:67:d6:e3:3e:f5:e3:d6:12:5e:44:f1:
bf:71:42:7d:58:84:03:80:b1:81:01:fa:f9:ca:32:


seed@VM: ~/.../AC_lab4
seed@VM: ~/.../AC_lab4
seed@VM: ~/.../AC_lab4
seed@VM: ~/.../AC_lab4
seed@VM: ~/.../AC_lab4
CA Issuers - URI:http://cacerts.digicert.com/DigiCertGlobalRootC
A.crt
X509v3 CRL Distribution Points:
Full Name:
URI:http://crl3.digicert.com/DigiCertGlobalRootCA.crl
X509v3 Certificate Policies:
Policy: 2.16.840.1.114412.2.1
Policy: 2.23.140.1.1
Policy: 2.23.140.1.2.1
Policy: 2.23.140.1.2.2
Policy: 2.23.140.1.2.3
Signature Algorithm: sha256WithRSAEncryption
80:32:ce:5e:0b:dd:6e:5a:0d:0a:af:e1:d6:84:cb:c0:8e:fa:
85:70:ed:da:5d:b3:0c:f7:2b:75:40:fe:85:0a:fa:f3:31:78:
b7:70:4b:1a:89:58:ba:80:bd:f3:6b:1d:e9:7e:cf:0b:ba:58:
9c:59:d4:90:d3:fd:6c:fd:d0:98:6d:b7:71:82:5b:cf:6d:0b:
5a:09:d0:7b:de:c4:43:d8:2a:a4:de:9e:41:26:5f:bb:8f:99:
cb:dd:ae:e1:a8:6f:9f:87:fe:74:b7:1f:1b:20:ab:b1:4f:c6:
f5:67:5d:5d:9b:3c:e9:ff:69:f7:61:6c:d6:d9:f3:fd:36:c6:
ab:03:88:76:d2:4b:2e:75:86:e3:fc:d8:55:7d:26:c2:11:77:
df:3e:02:b6:7c:f3:ab:7b:7a:86:36:6f:b8:f7:d8:93:71:cf:
86:df:73:30:fa:7b:ab:ed:2a:59:c8:42:84:3b:11:17:1a:52:
f3:c9:0e:14:7d:a2:5b:72:67:ba:71:ed:57:47:66:c5:b8:02:
4a:65:34:5e:8b:d0:2a:3c:20:9c:51:99:4c:e7:52:9e:f7:6b:
11:2b:0d:92:7e:1d:e8:8a:eb:36:16:43:87:ea:2a:63:bf:75:
3f:eb:de:c4:03:bb:0a:3c:f7:30:ef:eb:af:4c:fc:8b:36:10:
73:3e:f3:a4



Step 4

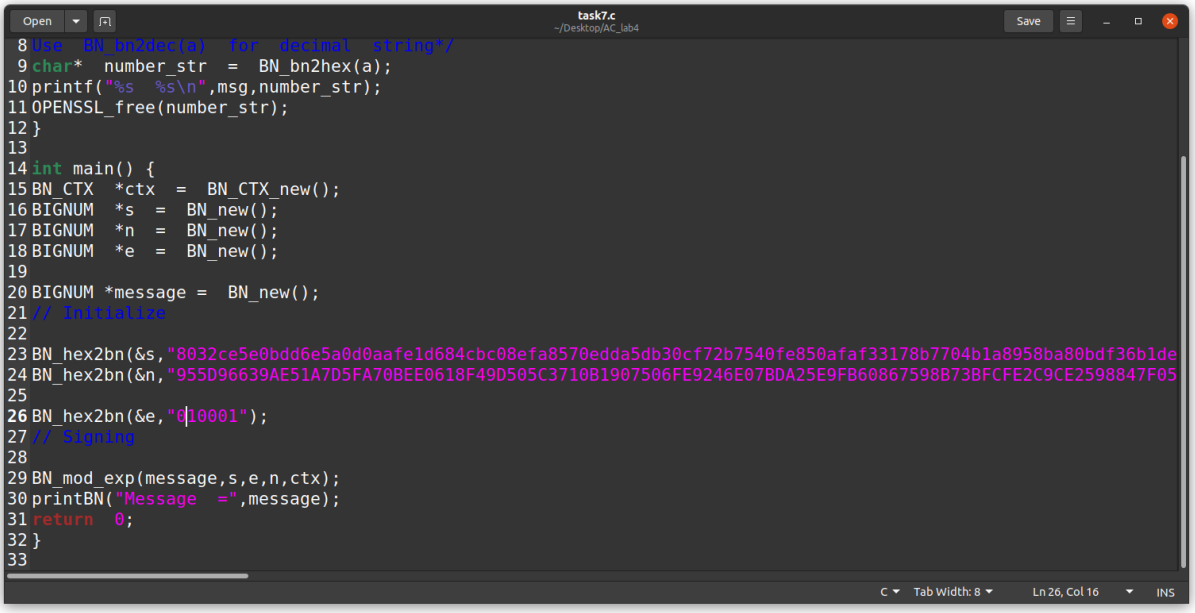
Verify the signature by substituting the values just found out, in the code given below and running it.

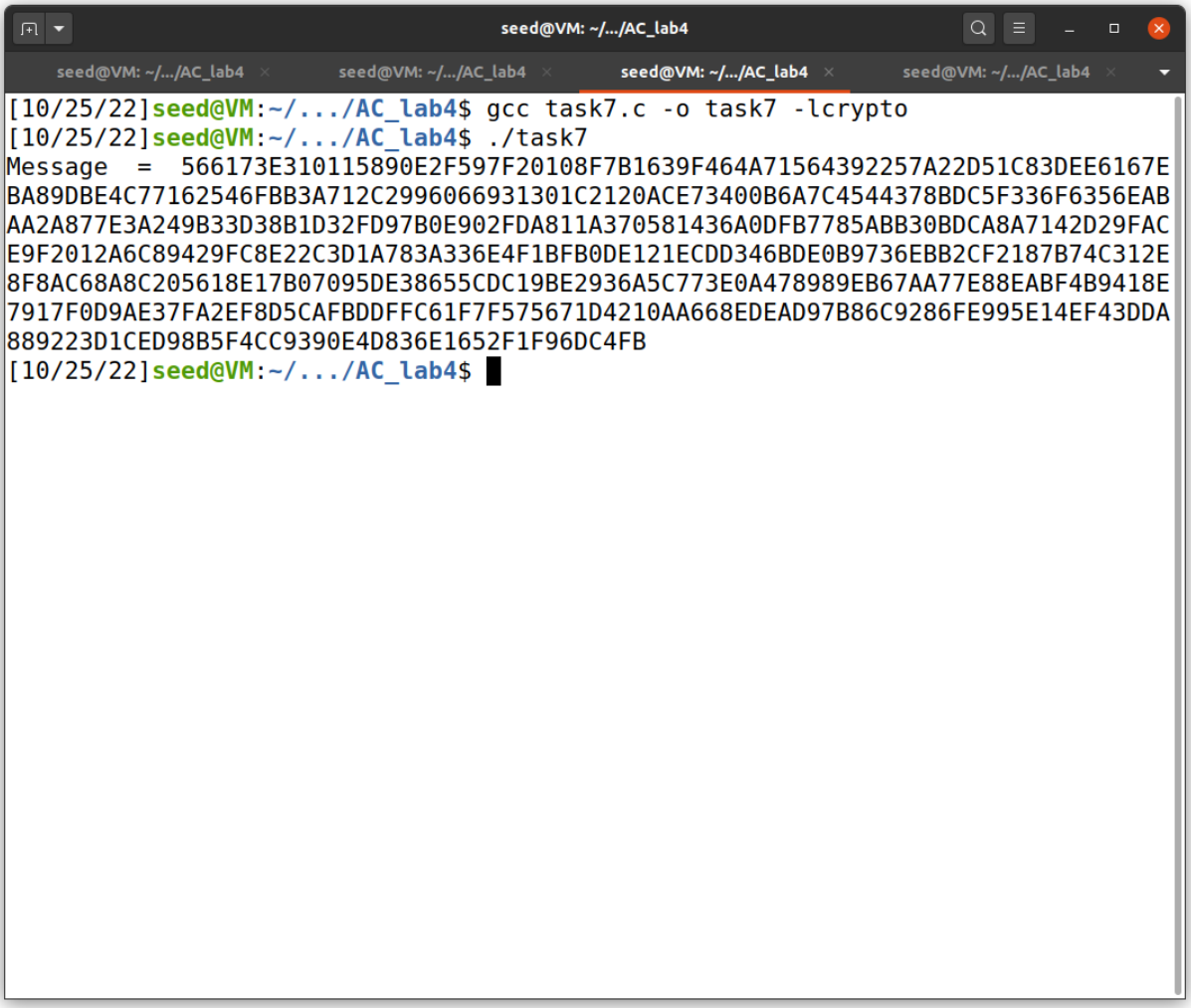
Code

```
#include <stdio.h>
#include <openssl/bn.h>
#define NBITS 256
void printBN(char*msg, BIGNUM*a) {
    /* Use BN_bn2hex(a) for hex string
        Use BN_bn2dec(a) for decimal string*/
    char* number_str = BN_bn2hex(a);
    printf("%s %s\n",msg,number_str);
    OPENSSL_free(number_str);
}
int main() {
    BN_CTX *ctx = BN_CTX_new();
    BIGNUM *s = BN_new();
    BIGNUM *n = BN_new();
    BIGNUM *e = BN_new();
    BIGNUM *message = BN_new();
    // Initialize
    BN_hex2bn(&s,"<< signature >>");
    BN_hex2bn(&n,"<< modulus >>");
    BN_hex2bn(&e,"<< exponent >>");
    // Signing
    BN_mod_exp(message,s,e,n,ctx);
    printBN("Message =",message);
    return 0;
}
```

Commands

```
$ gcc task7.c -o  task7 -lcrypto
$ ./task7
```





We will substitute modulus, exponent and signature and find the message