18-631 INFORMATION SECURITY HOME WORK 3
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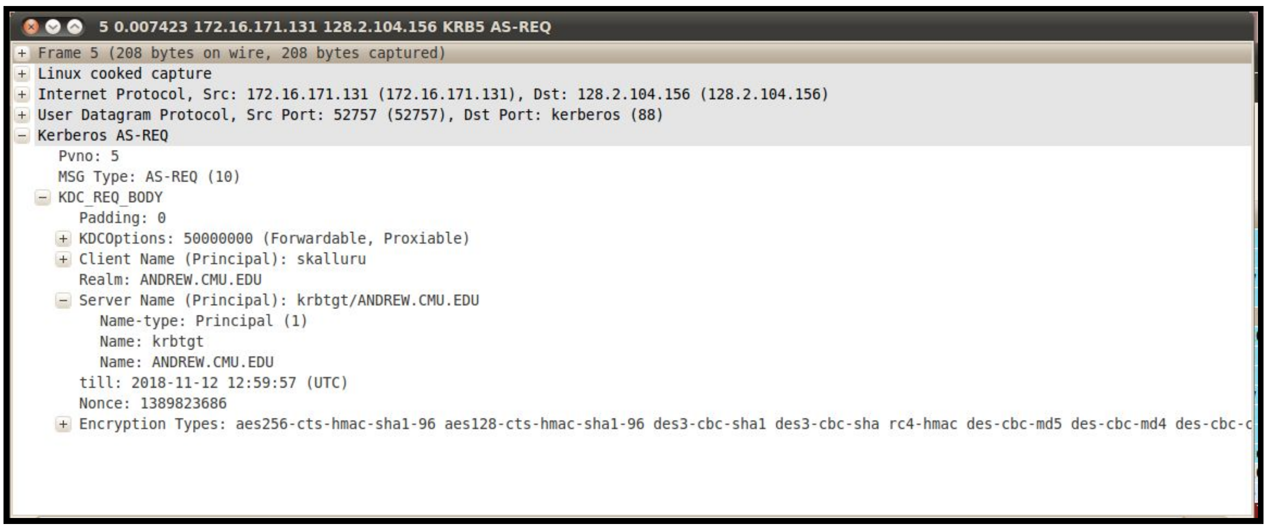
QUESTION 1 - KERBEROS WIRESHARK

1) Step 6 is optional, because Server can certify only if it wishes to or not. Because the Authenticator’C is encrypted with shared key between C(client) and Server (V). A Server (V) should not be able to decrypt the ticket unless it has the key associated with the Kerberos principal. If it can't decrypt the service ticket then it shouldn't have access to the information about the Client (C) which it needs to properly authenticate and create a session for that client. Therefore the mere fact that the server is able to construct a reply to C is itself sufficient to say that the right server has responded.
2) 2.1) I am running Kerberos Version 5 (Pvno : 5) as shown by the packet below



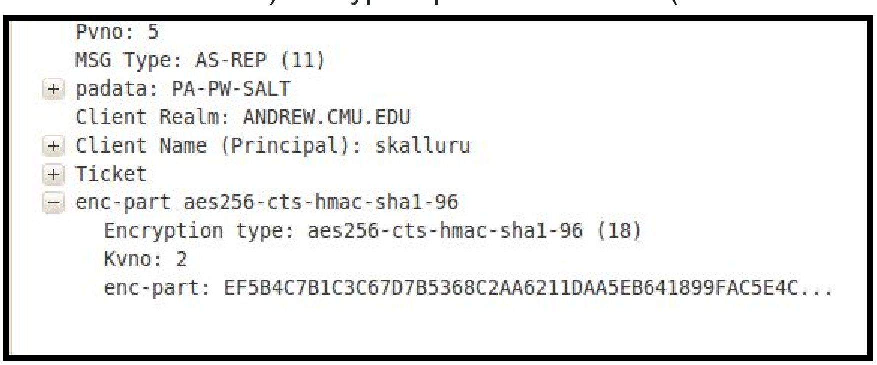
```
5 0.007423 172.16.171.131 128.2.104.156 KRB5 AS-REQ
+ Frame 5 (208 bytes on wire, 208 bytes captured)
+ Linux cooked capture
+ Internet Protocol, Src: 172.16.171.131 (172.16.171.131), Dst: 128.2.104.156 (128.2.104.156)
+ User Datagram Protocol, Src Port: 52757 (52757), Dst Port: kerberos (88)
- Kerberos AS-REQ
    Pvno: 5
    MSG Type: AS-REQ (10)
  - KDC_REQ_BODY
      Padding: 0
    + KDCOptions: 50000000 (Forwardable, Proxiable)
    + Client Name (Principal): skalluru
      Realm: ANDREW.CMU.EDU
    - Server Name (Principal): krbtgt/ANDREW.CMU.EDU
        Name-type: Principal (1)
        Name: krbtgt
        Name: ANDREW.CMU.EDU
      till: 2018-11-12 12:59:57 (UTC)
      Nonce: 1389823686
    + Encryption Types: aes256-cts-hmac-sha1-96 aes128-cts-hmac-sha1-96 des3-cbc-sha1 des3-cbc-sha rc4-hmac des-cbc-md5 des-cbc-md4 des-cbc-c
```

2.2) Server Name : **krbtgt** , ANDREW.CMU.EDU

2.3) Client Name : skalluru (my andrew ID)

2.4) Encryption type used : aes256 - cts - hmac - sha1 - 96

2.5) Encrypted part: EC5B4C7B (first 8 letters of encrypted part)



```
  Pvno: 5
  MSG Type: AS-REP (11)
+ padata: PA-PW-SALT
  Client Realm: ANDREW.CMU.EDU
+ Client Name (Principal): skalluru
+ Ticket
- enc-part aes256-cts-hmac-sha1-96
    Encryption type: aes256-cts-hmac-sha1-96 (18)
    Kvno: 2
    enc-part: EF5B4C7B1C3C67D7B5368C2AA6211DAA5EB641899FAC5E4C...
```

3.1)Output of KLIST 2

```
user@netsec-hw:~$ klist
Credentials cache: FILE:/tmp/krb5cc_1000
        Principal: skalluru@ANDREW.CMU.EDU

  Issued           Expires          Principal
Nov 11 21:59:57  Nov 12 07:59:57  krbtgt/ANDREW.CMU.EDU@ANDREW.CMU.EDU
user@netsec-hw:~$
```

3.2) Currently only one ticket is valid

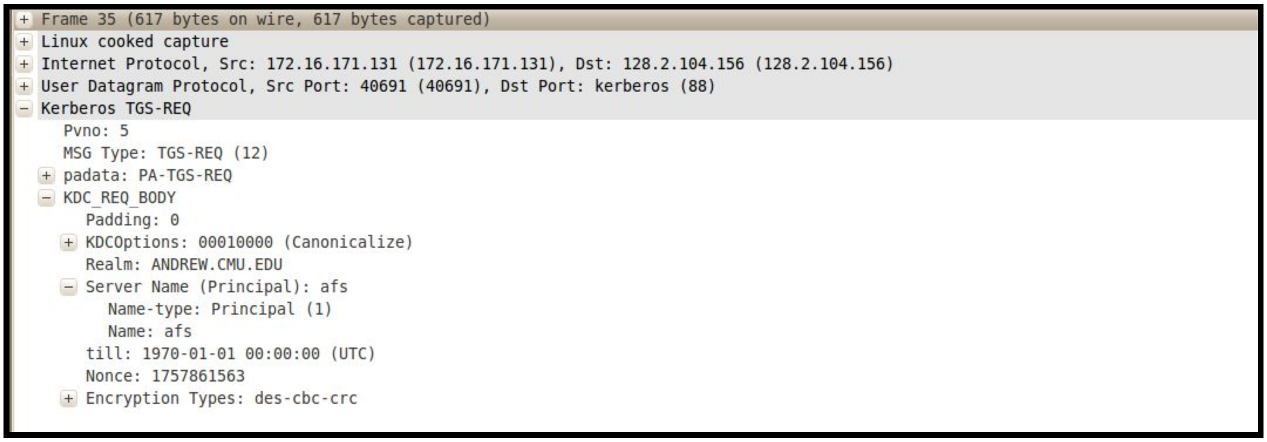
3.3) It is valid for 10 hours (NOV11 9PM - NOV12 8AM)

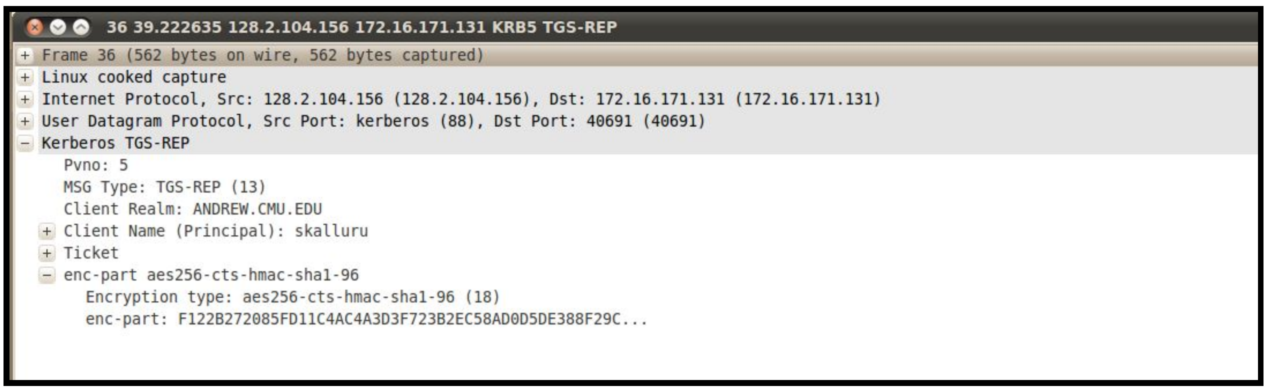
3.4) principals involved are : **skalluru and krbtgt/ANDREW.CMU.EDU@ANDREW.CMU.EDU**

4.1) The four packets of AS REQ, AS REP, TGS REQ and TGS REP are shown below

```
23 38.946726 172.16.171.131 128.2.104.156 KRB5 AS-REQ
+ Frame 23 (208 bytes on wire, 208 bytes captured)
+ Linux cooked capture
+ Internet Protocol, Src: 172.16.171.131 (172.16.171.131), Dst: 128.2.104.156 (128.2.104.156)
+ User Datagram Protocol, Src Port: 47987 (47987), Dst Port: kerberos (88)
- Kerberos AS-REQ
    Pvno: 5
    MSG Type: AS-REQ (10)
  - KDC_REQ_BODY
      Padding: 0
    + KDCOptions: 50000000 (Forwardable, Proxiable)
    + Client Name (Principal): skalluru
      Realm: ANDREW.CMU.EDU
    - Server Name (Principal): krbtgt/ANDREW.CMU.EDU
        Name-type: Principal (1)
        Name: krbtgt
        Name: ANDREW.CMU.EDU
      till: 2018-11-12 13:18:56 (UTC)
      Nonce: 258153979
    + Encryption Types: aes256-cts-hmac-sha1-96 aes128-cts-hmac-sha1-96 des3-cbc-sha1 des3-cbc-sha rc4-hmac des-cbc-md5 des-cbc-md4 des-cbc-crc
```

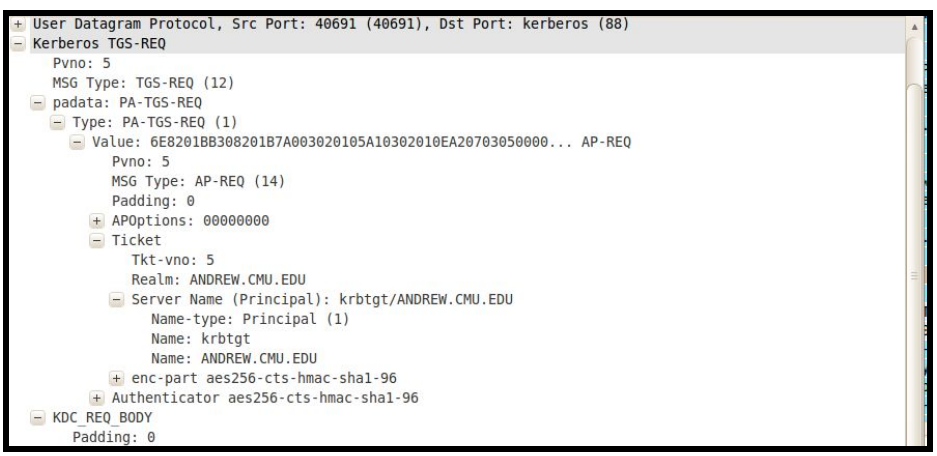
```
- Kerberos AS-REP
    Pvno: 5
    MSG Type: AS-REP (11)
  + padata: PA-PW-SALT
    Client Realm: ANDREW.CMU.EDU
  + Client Name (Principal): skalluru
  + Ticket
  - enc-part aes256-cts-hmac-sha1-96
      Encryption type: aes256-cts-hmac-sha1-96 (18)
      Kvno: 2
      enc-part: 4D7EA93EC1C38D8CA9F1801EFBB347032FC0E37304F8272E...
```





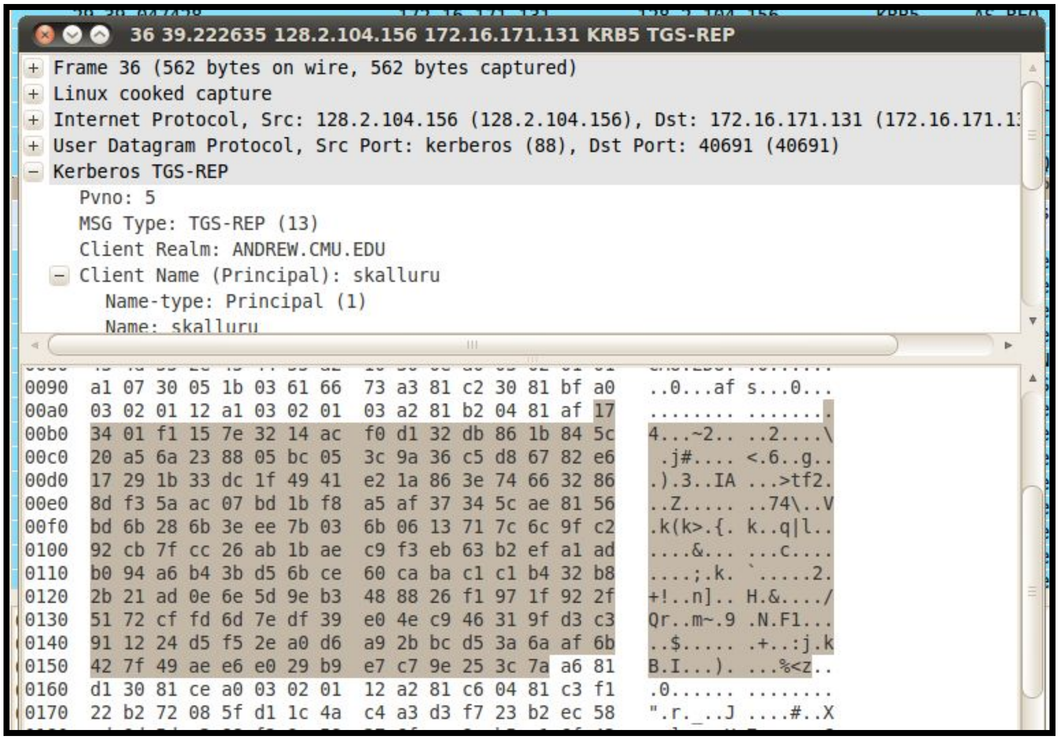
4.2) The name of the server can be found in TGS REQ as the ID_V of the server is sent in plain text in request to Ticket granting server. The name of the server is : ANDREW FILE SYSTEM - **afs**

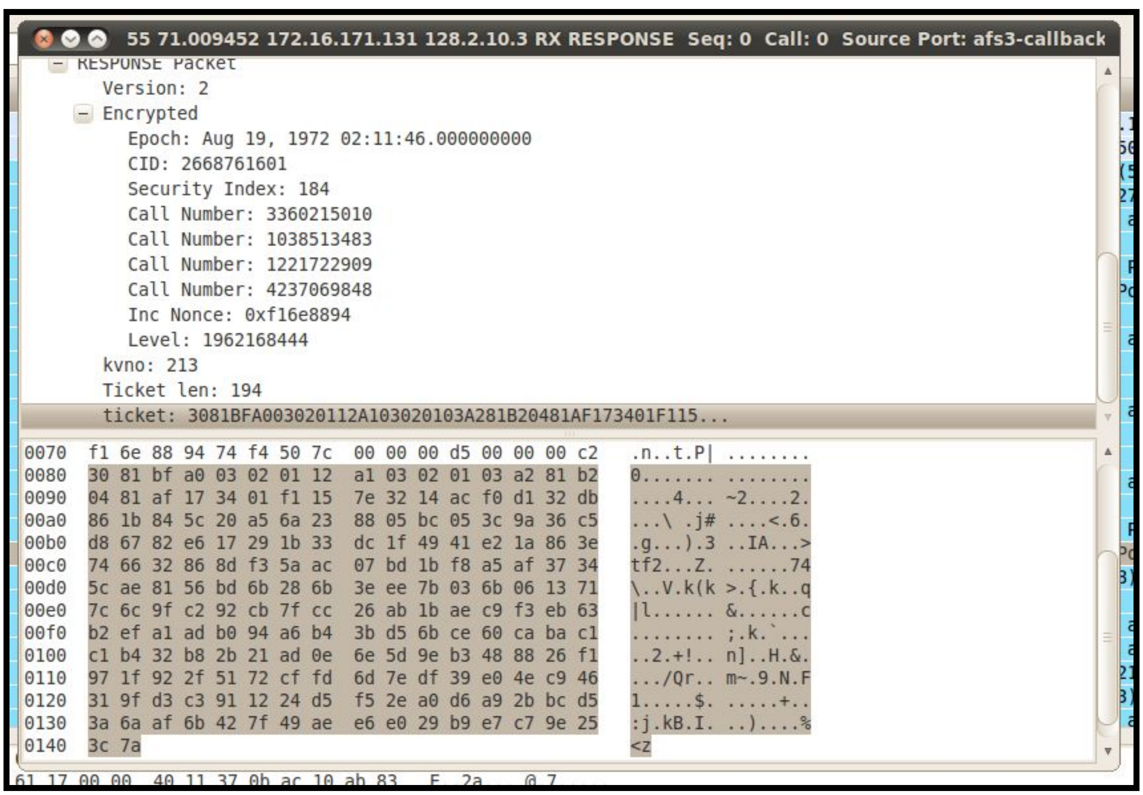
4.3)



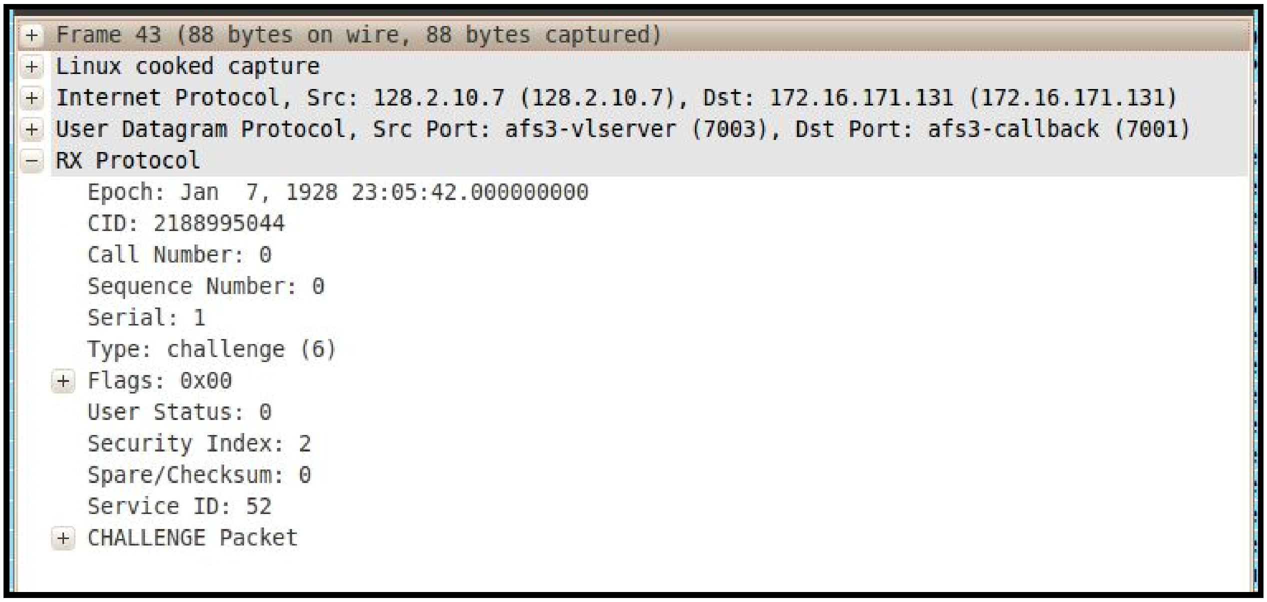
From TGS-REQ , we can see there is Ticket block being sent in the packet, which proves that the ticket from Authentication Server is sent to TGS - Ticket Granting server.

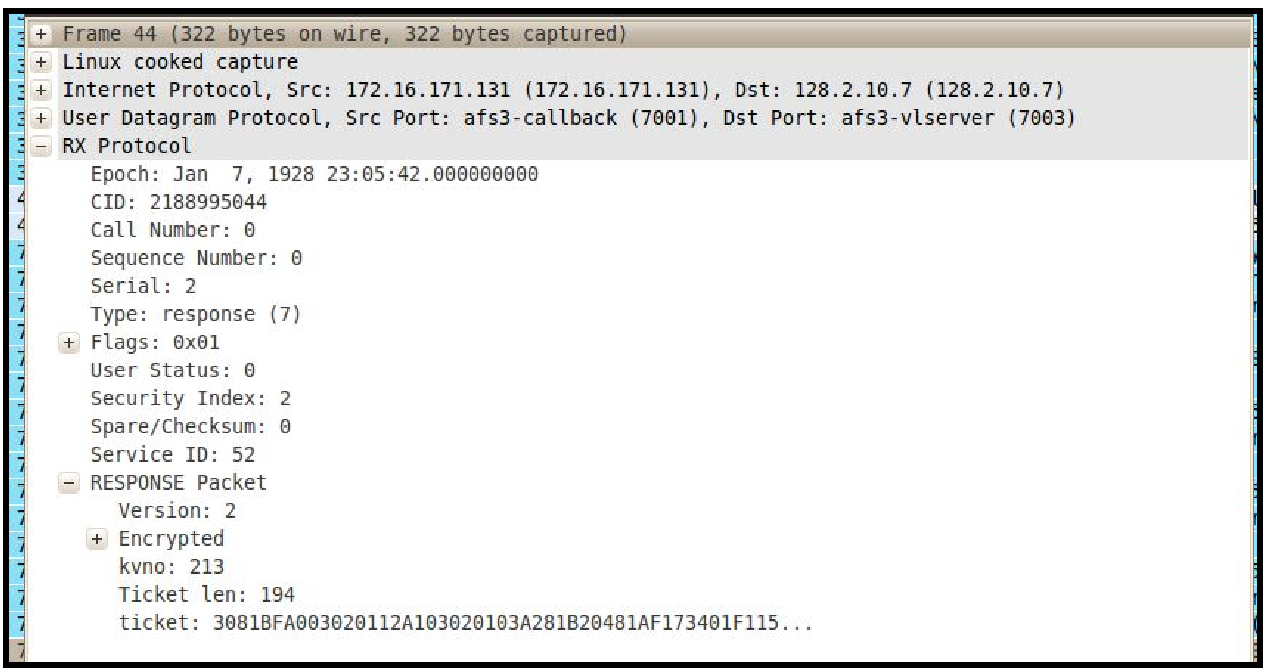
4.4) We can see from the ticket given from TGS - REP is given by client to server.
The value of the ticket starts from 173401f1157e32 in TGS REP (line 00a0 to 0150), which is also available in RX response (line 0090 to 0140 ending with 25 3c 7a).





4.5) Mutual Authentication is used, because we can see an RX CHALLENGE and an RX RESPONSE packet. Which implies that the client is asking AFS to authenticate itself, for which the server responds to that challenge. Frame 43 - RX - CHALLENGE packet
Frame 44 - RX RESPONSE packet.





5.1)

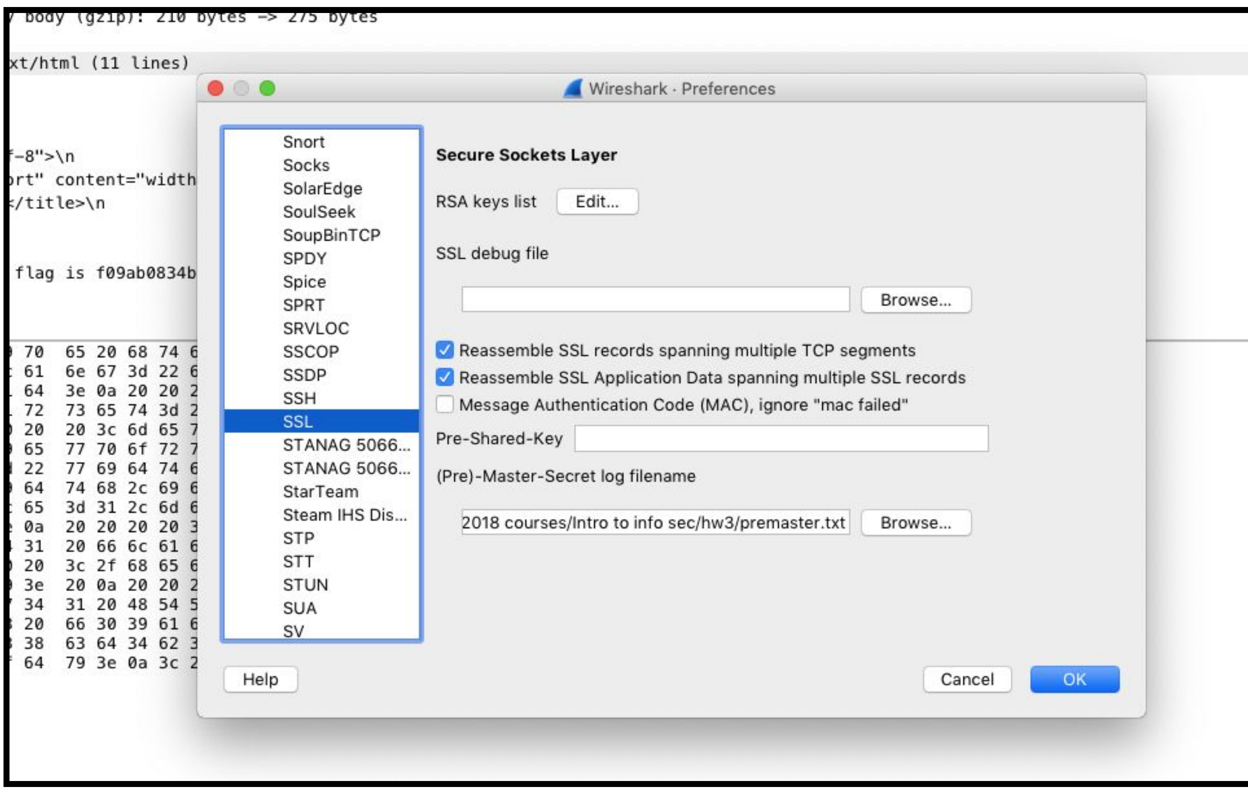
```
user@netsec-hw:~$ klist
Credentials cache: FILE:/tmp/krb5cc_1000
        Principal: skalluru@ANDREW.CMU.EDU

  Issued           Expires          Principal
Nov 11 22:18:56  Nov 12 08:18:56  krbtgt/ANDREW.CMU.EDU@ANDREW.CMU.EDU
Nov 11 22:18:56  Nov 12 08:18:56  afs@ANDREW.CMU.EDU
```

5.2) Two tickets are valid
5.3) Both of them expire in 12 hours
5.4) Three principals are involved:

- skalluru
- krbtgt/ANDREW.CMU.EDU@ANDREW.CMU.EDU
- afs@ANDREW.CMU.EDU

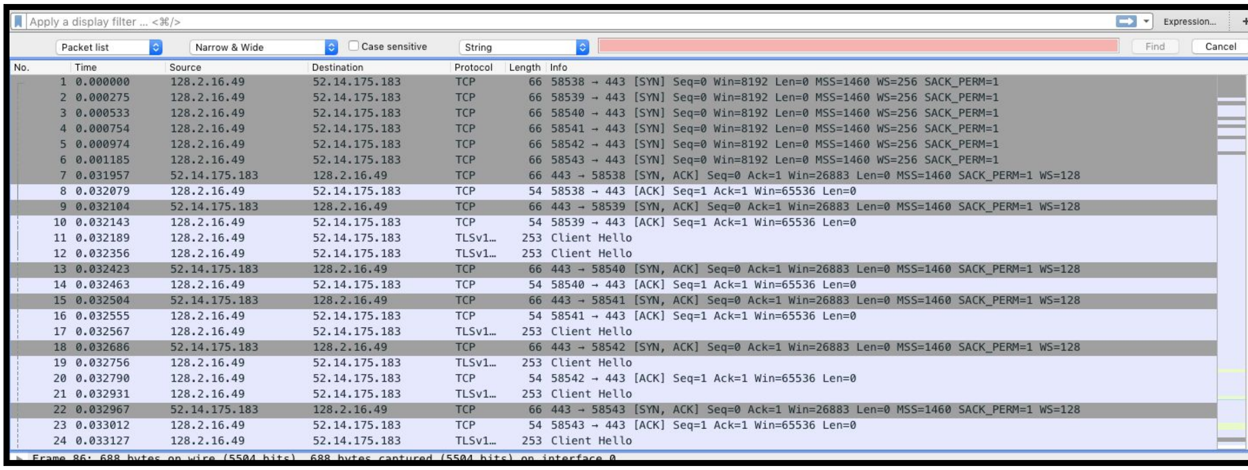
2. DECRYPTING SSL TRAFFIC

- SSL Traffic is captured in ***picoctf ssl flag1.pcapng*** file. The traffic capture can be parsed using Wireshark.
- Once we open the capture in wireshark, we can see red lines, which shows the encrypted part of the traffic. We have to decrypt this traffic to see the entire SSL handshake.
- The SSL traffic can be decrypted by using premaster.txt log file. This log file is generated by browser, (if set to TRUE) during SSL sessions. The log file contains keys that could decrypt the SSL traffic.
- We can add the premaster.txt key log file in the Wireshark to decrypt the traffic.
- The procedure to add premaster.txt log file is as follows
    - First, we should check if wireshark version is latest.
    - Second we should add a system variable named SSLKEYLOGFILE having the value as location to premaster.txt (ex : C\temp\premaster.txt)
    - We should then go to edit preferences menu in Wireshark, and choose SSL in protocols section as shown below

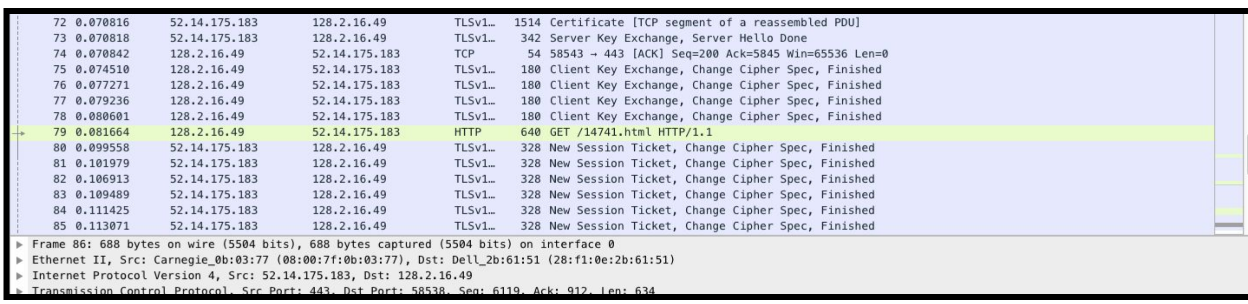


    - In the menu, we can edit the path to premaster secret log filename and its path.

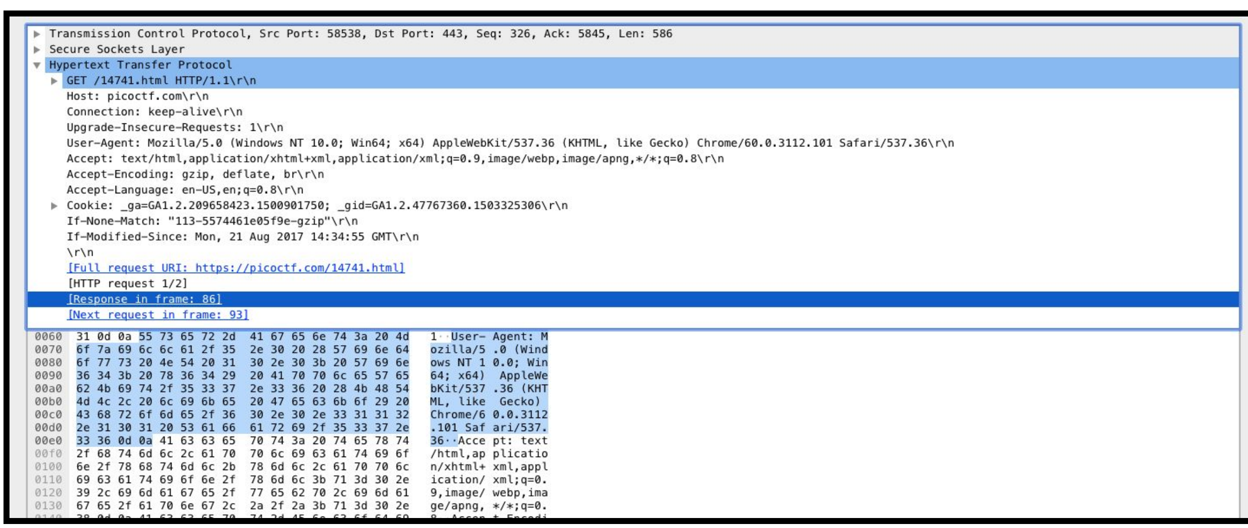
- The wireshark will use this premaster.txt file and decrypt the traffic as shown below

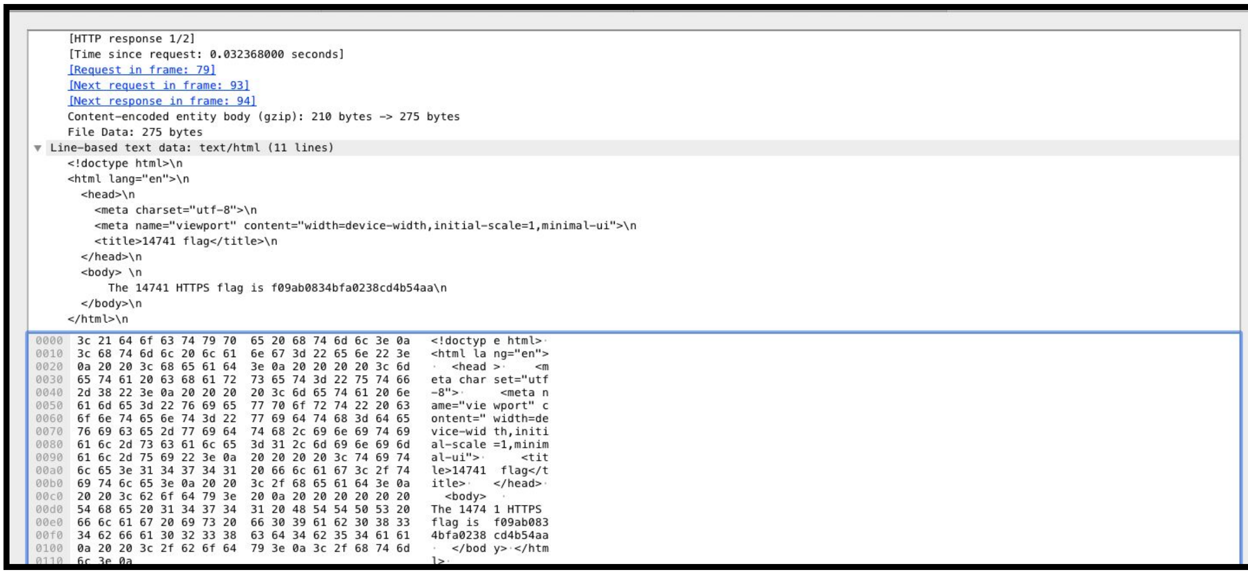


- The dark grey lines show the traffic that is decrypted.
- We can now clearly see and distinguish between client hello, server hello and all other handshakes between them.
- To find the flag, we have to look for an HTML handshake between server and client, which was discovered :



- The HTML GET request has the packet details as follows:

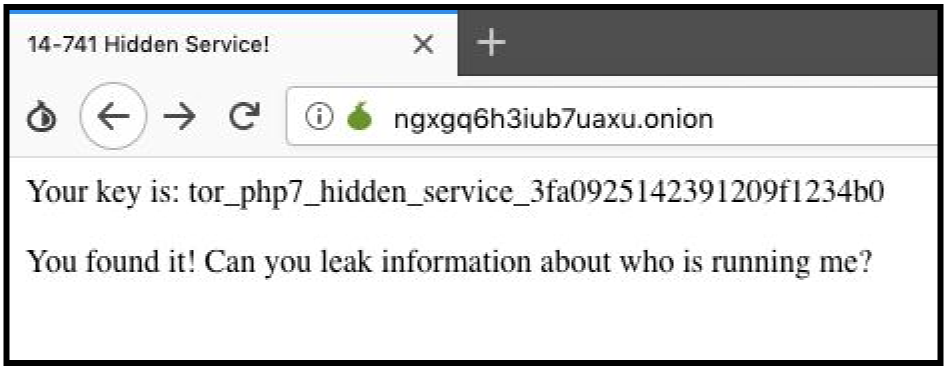


- The packet details say that, the response to the packet is in Frame : 86. Therefore, if we open frame 86 and expand the HTML inline text , we can see the flag
- 

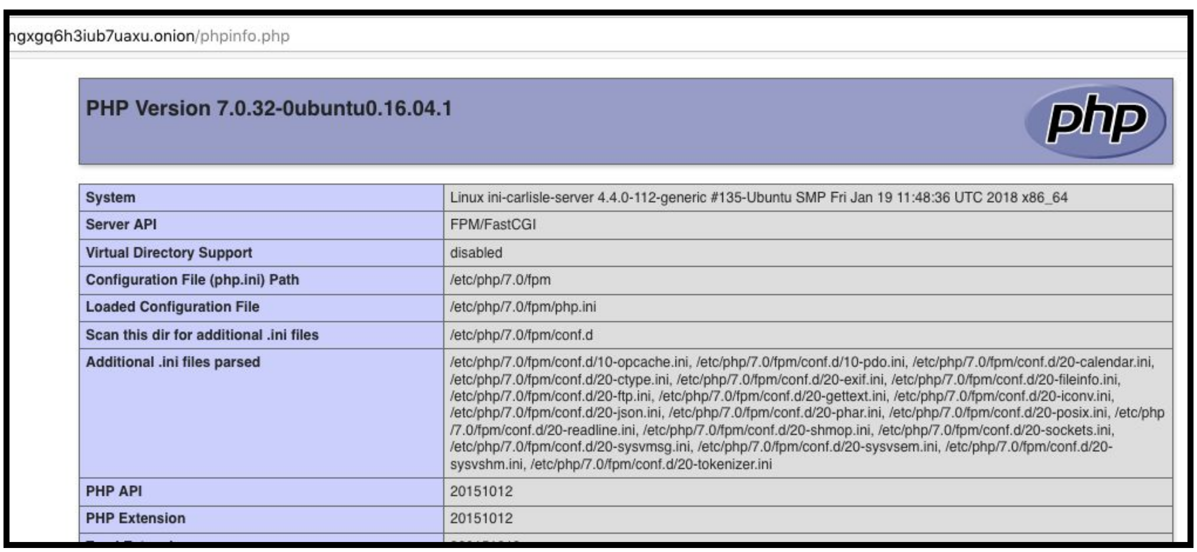
- In this way we can decrypt the SSL traffic and get the data sent between server and client, given that we have session logs saved by the browser.
- Please zoom into the pictures for letters to become more legible.
- THe flag is found to be : ***f09ab0834bfa0238cd4b54aa***
- The environmental variable used for chrome is : SSLKEYLOGFILE
- HTTPS is secure, even though it can decrypted is because, we need the private keys to decrypt this traffic, and these keys are **available only at the client side** browser that requested for the handshake, and will not be available with the man in the middle.
- HTTPS adds security and trust as the MiTM cannot alter the packet while it is in transit.

3. TOR HIDDEN SERVICE

- Tor - is an online anonymity services provider.
- Tor hidden services are used by individuals or organisations to run servers that are not easier to track (provides anonymity to server information, hostname, and other details)
- However if the service is not configured properly, The service might be vulnerable to spill some valuable information about the server to any hacker.



-
- From this picture we can see that, the key is being spilled out by *onion* service. In the key, we get information about the kind of service it is using - *php* service.
- Because of this leak of information we have come to know that we can use - ***php information disclosure vulnerability*** - which would provide valuable information about the server.
- Just by changing the URL as - http://ngxgq6h3iub7uaxu.onion/**phpinfo.php** **,** the part in bold can be added to the onion service URL and we can get information about the server as shown below.



ngxgq6h3iub7uaxu.onion/phpinfo.php

PHP Version 7.0.32-0ubuntu0.16.04.1

System	Linux ini-carlisle-server 4.4.0-112-generic #135-Ubuntu SMP Fri Jan 19 11:48:36 UTC 2018 x86_64
Server API	FPM/FastCGI
Virtual Directory Support	disabled
Configuration File (php.ini) Path	/etc/php/7.0/fpm
Loaded Configuration File	/etc/php/7.0/fpm/php.ini
Scan this dir for additional .ini files	/etc/php/7.0/fpm/conf.d
Additional .ini files parsed	/etc/php/7.0/fpm/conf.d/10-opcache.ini, /etc/php/7.0/fpm/conf.d/10-pdo.ini, /etc/php/7.0/fpm/conf.d/20-calendar.ini, /etc/php/7.0/fpm/conf.d/20-ctype.ini, /etc/php/7.0/fpm/conf.d/20-exif.ini, /etc/php/7.0/fpm/conf.d/20-fileinfo.ini, /etc/php/7.0/fpm/conf.d/20-ftp.ini, /etc/php/7.0/fpm/conf.d/20-gettext.ini, /etc/php/7.0/fpm/conf.d/20-iconv.ini, /etc/php/7.0/fpm/conf.d/20-json.ini, /etc/php/7.0/fpm/conf.d/20-phar.ini, /etc/php/7.0/fpm/conf.d/20-posix.ini, /etc/php/7.0/fpm/conf.d/20-readline.ini, /etc/php/7.0/fpm/conf.d/20-shmop.ini, /etc/php/7.0/fpm/conf.d/20-sockets.ini, /etc/php/7.0/fpm/conf.d/20-sysvmsg.ini, /etc/php/7.0/fpm/conf.d/20-sysvsem.ini, /etc/php/7.0/fpm/conf.d/20-sysvshm.ini, /etc/php/7.0/fpm/conf.d/20-tokenizer.ini
PHP API	20151012
PHP Extension	20151012

- From this page, a hacker can get most information about the server and the services enabled on the server, which could be valuable for bringing down an attack.
- We can see that the server is ***Linux Ubuntu 0.16.04.1***
- We can also see that the host name is - ***ini-carlisle-server.*** Therefore **no longer anonymous.**

4. ALICE AND BOB - PART 1

1. If attacker gets K'_AB, the attacker would not be able to read messages M1 and M2, because Hash functions are NOT REVERSIBLE FUNCTIONS. As in, knowing the output we cannot determine the input to the function. In order to determine messages M1 and M2 we need key K, since K is not obtainable from K'_AB we can safely conclude that all messages from previous sessions **cannot be decrypted**. The previous session **remains a secret.**
2. However, if the attacker obtains K'AB, he can compute the H(K'AB) because the Hash function is **publicly available**. Therefore if he gets hold of one session key, Attacker can pretty much decoded the hash of the available key and use it to decrypt the messages in future sessions. The future session **does not remain a secret anymore.**
3. In this protocol Alice and Bob, use diffie Hellman key exchange. However they are encrypted using K_AB. Getting hold of K_AB does not allow the hacker to deduce messages in previous sessions. The messages in previous sessions are encrypted with Key K which is derived from diffie Hellman exchange and not from K_AB itself. Having K_AB would give access to g^a mod p and g^b mod p, however key K = g^(ab) mod p is possible only when the attacker get either *a* or *b* separately. Since g^x mod p is not a reversible function the attacker would not be able to get either random number 'a' or random number 'b'.
4. The same explanation as earlier would be the reasoning to state that the attacker cannot decrypt messages of both **previous and future sessions** (because the key that **encodes the message - M** for future sessions is not **derived** from past sessions).
5. **COMMENTS : Answers for questions 4.3 and 4.4,** assumes that there is **no Man in the Middle attack** and it also assumes that the **random number *a* and *b* are not predictable.** If either of these assumptions becomes true, then this protocol would fail to keep the message a secret. In comparison to protocol shown in subdivision 1 and 2, the protocol in subdivision 3 and 4 performs better as it protects both past and future sessions.

5. ALICE AND BOB - PART 2

- Security properties ensured in Bob's protocol :
  - Confidentiality / Secrecy is enforced - because the message can be decrypted only by using Bob's private key
  - Integrity - the data if tampered with, will tamper the data of the sender name as well. Therefore the validity of the data will not exist and therefore Bob would discard.
- Alice made a mistake by removing the sender's name in her protocol, In Alice's protocol data integrity will not be ensured. Because if the data X is tampered with, then there is no way to determine if it is a valid message or not. Whereas in Bob's protocol if the data is tampered with, sender's name also gets tampered and therefore the receiver can understand that the data is tampered and discard it. Therefore Alice is ***wrong*** in assuming that bob's protocol comes down to just sending the message alone.
- The protocol can be enhanced by using ***timestamp*** along with the sender name and message. The receiver can discard the message when the timestamp is far in the past, above a threshold time value (t secs) . The threshold time value(t secs) can be set by choosing the value such that, it would be less time for mallory / attacker to replay a packet within that time.
- Even for freshness - ***Timestamps*** can be used :
  - A ---> B : ENC :{A,X,T_A} using K_AB
  - After some threshold time t, if Mallory (M) replays the same packet (***ENC :{A,X,T_A} using K_AB***) , then B will discard the packet because, the valid timestamp at that instance would be T_B and not T_A.
  - In other words ,if mallory replays the same packet again ,timestamp T_A would have expired.
  - Timestamps are *nonces* . Nonces can be used to bring freshness into protocol and prevent replay attacks.
- Nonces should not be predictable - However time stamps could be predictable, therefore there is a need to find NON PREDICTABLE NONCES, for Mallory not to create a new packet with a predictable nonce and impersonate Alice to Bob.

6. SQL INJECTION CTF USERNAME - kssaivineeth15

6. For solving the SQL Injection, we can follow the following steps
    - Right click and open - view page source - to view the HTML of the page source
    - Click on the PHP page with <a href> tag in the HTML page
    - The php page looks like below

```php
<?php
  include "config.php";
  $con = new SQLite3($database_file);

  $username = $_POST["username"];
  $password = $_POST["password"];
  $debug = $_POST["debug"];
  $dog = $_POST["dog"];
  $query = "SELECT * FROM users WHERE name='$username' AND password='$password'";
  $result = $con->query($query);
  if (intval($debug)) {
    echo "<pre>";
    echo "username: ", htmlspecialchars($username), "\n";
    echo "password: ", htmlspecialchars($password), "\n";
    echo "dog: ", htmlspecialchars($dog), "\n";
    echo "SQL query: ", htmlspecialchars($query), "\n";
    echo "</pre>";
  }

  $row = $result->fetchArray();

  if ($row && (strcasecmp($dog, 'scotty') == 0)) {
    echo "<h1>Logged in!</h1>";
    echo "<p>Your flag is: $FLAG</p>";
  } else {
    echo "<h1>Login failed.</h1>";
  }
?>
```

    -
    - The query variable in PHP script handles the SQL query to the database.
    - This query is prone to SQL injection
    - The username and password field values from the HTML page is directly added into the variables $username and $password
    - We can also notice that if the *dog* field is given as ‘scotty’ we can ensure that the ***if*** condition can become true execute.
    - Therefore we can see that the dog field variable has to be ‘scotty’
    - For the username and password fields, we need not find out the username or password, instead we can inject SQL code such that the $query turns out to be a valid SQL query.
    - To make it valid we can inject multiple varieties of SQL code. I chose
    - ***' OR '1'='1*** for both username and password fields.
    - This injection of SQL code changes the $query to SELECT * FROM users WHERE name = ‘ ***1 ‘ OR ‘1’ = ‘ 1*** ’ AND password = ‘***1 ‘ OR ‘1’ = ‘ 1***’
    - We can see that even though there is no name with ‘1’ value or password with ‘1’ value, the OR statement in both cases will make either side of AND as TRUE, this will make the entire SQL statement TRUE.
    - This code will make the ***if*** condition become true and allow me to login and print the FLAG.

7. BLIND SQL INJECTION CTF USERNAME - kssaivineeth15

7. For solving the SQL Injection, we can follow the following steps
    - Right click and open - view page source - to view the HTML of the page source
    - Click on the PHP page with <a href> tag in the HTML page
    - The login.php page looks like below

```php
<?php
  include "config.php";
  $con = new SQLite3($database_file);

  $username = $_POST["username"];
  $password = $_POST["password"];
  $debug = $_POST["debug"];
  $dog = $_POST["dog"];
  $query = $con->prepare('SELECT * FROM users WHERE name=:username AND password=:password AND dog=:dog');
  $query->bindValue(':username',$username,SQLITE3_TEXT);
  $query->bindValue(':password',$password,SQLITE3_TEXT);
  $query->bindValue(':dog',$dog,SQLITE3_TEXT);
  $result = $query->execute();
  if (intval($debug)) {
    echo "<pre>";
    echo "username: ", htmlspecialchars($username), "\n";
    echo "password: ", htmlspecialchars($password), "\n";
    echo "dog: ", htmlspecialchars($dog), "\n";
    echo "</pre>";
  }

  $row = $result->fetchArray();

  if ($row) == 0) {
    echo "<h1>Logged in!</h1>";
    echo "<p>Your flag is: $FLAG</p>";
  } else {
    echo "<h1>Login failed.</h1>";
  }
?>
```

    - In login.php the fields $username and $password are NOT INJECTABLE as they are passed as SQL PARAMETERS, which get executed only at the runtime of the query. Once they are binded as parameters it is impossible to inject SQL code, as the variables $username and $password are treated as values AND NOT AS A PART OF THE SQL QUERY STRING.
    - However we provided with another html page - game.html which as game.php as shown below.

- ```php
  <?php
    include "config.php";
    $con = new SQLite3($database_file);

    $id = $_POST["id"];
    $debug = $_POST["debug"];
    $query = "SELECT * FROM games WHERE ID='$id'";
    $result = $con->query($query);
    if (intval($debug)) {
      echo "<pre>";
      echo "id: ", htmlspecialchars($id), "\n";
      echo "</pre>";
    }

    $row = $result->fetchArray();

    if ($row) {
      echo "<h1>I know that game!</h1>";
    } else {
      echo "<h1>What game is that?</h1>";
    }
  ?>
  ```
- In game.php we can see that both login.php and game.php use the same database file. Also the SQL query in games.php is NOT BINDED AS SQL PARAMETER hence VULNERABLE for SQL INJECTION ATTACK.
- Here the SQL query asks for an ID value from *games* table. However since both *users* and *games* table are present in the same database. We can access *users* table by injecting SQL code into the *games* table query.
- We can achieve this using UNION statement in SQL .
- On checking the value of 1 for ID, we can see that the webpage displays - ‘ I KNOW THAT GAME’ which implies that the SQL query is a valid SQL query. Otherwise it displays ‘ WHAT GAME IS THAT?’
- This gives us a confirmation that, we cannot directly see the values in the users table, however given a set of conditions we can make this a TRUE/ FALSE problem and try to hit a valid sql query.
- We are given in the hint that the username is ‘admin’ and the dog is ‘scotty’ therefore our only concern is with password.
- A general UNION statement in SQL looks like below:
  - SELECT _____ FROM games WHERE ID = ‘ ***1 ‘ UNION SELECT ____ FROM users --*** ‘
  - From the above query, the dashes represent the number of columns required from the selected tables, for UNION statement to work, both sides of UNION statement has to request for equal number of tables.
  - UNION concatenates the output from both queries and gives the union of the output - or in other words makes the SQL query TRUE.
  - We can keep changing the other side of the query and check its validity by check if the UNION statement becomes TRUE.
  - We are interested in *name* and *password* columns of *users* table, therefore we should request for two columns from *games* table as well.
  - To check the number of columns in games table we can try out the following query :
  ```

- SELECT * FROM games WHERE ID = ‘ **1 ‘ ORDER BY 2 --** ‘
- Order by helps us in finding out the maximum number of columns available in *games* table. As long as the SQL query is TRUE, the column value can be increased, once it becomes FALSE, the corresponding value would be the maximum set of columns in the table
    - Ex if ORDER BY 1 is TRUE and ORDER BY 2 is TRUE and ORDER BY 3 is false, then maximum number of columns in *games* table is 2.
- Therefore we should request for two tables in *users* table as well.
- SELECT ID, FROM games WHERE ID = ‘ ***1 ‘ UNION SELECT name, password FROM users --*** ‘ - This change to query will make it TRUE.
- However, we also know that *name* value is ‘admin’ therefore adding the above information we get
- SELECT ID, FROM games WHERE ID = ‘ ***1 ‘ UNION SELECT name, password FROM users WHERE name = ‘admin’--*** ‘
- We can brute force for password by using the following SQL statement.
    - SELECT ID, FROM games WHERE ID = ‘ ***1 ‘ UNION SELECT name, password FROM users WHERE name = ‘admin’ AND password LIKE ‘A%’-- ‘*** .
    - The above SQL query returns TRUE if there is a user named admin and their password starts with the value ‘A’. We can use this information and keep brute forcing values of all alphabets and numbers until we hit ‘ I KNOW THAT GAME’ response from the webpage. (However based on question hint, we need to bruteforce only hex characters ***0-9 , a-f***)
    - Every time we get a value we can update the SQL statement with the value found it and brute force the rest of characters.
    - SELECT ID, FROM games WHERE ID = ‘ ***1 ‘ UNION SELECT name, password FROM users WHERE name = ‘admin’ AND password LIKE ‘c%*** ‘
    - 

    - The password after brute forcing was found to be - ca05addc (Please zoom into for the letters in the image to become legible).
    - Adding the name = ‘admin’ and password = ‘ca05addc’ and dog = ‘scotty’. we get logged in and claim the flag.

SELECT ID FROM USERS WHERE USERNAME = 'ADMIN' AND SUBSTR(PASSWORD,1,1) == 'A'

SELECT ID FROM USERS WHERE USERNAME = 'ADMIN' AND PASSWORD LIKE 'A%'

SELECT ID FROM USERS WHERE USERNAME = 'ADMIN' UNION TABLENAME FROM TABLEES WHERE SUBSTR(TABLENAME,1,1) =='A' '

2) work on optional question

3)a) type klist in terminal to get the output
   b) only 1 ticket should be valid
   c) find expiry time
   d) two principals - myself and krbtgt/ANDREW.CMU.EDU

4) a) first four kerberos - after sorting with packet number
   b) find the server name in c -> TGS (TGS- REQ) server name - AFS

c) AS - REP for ticket in encrypted format, and TGS-REQ for ticket in ecrypted format
d) aes256-cts-hmac-sha1-96
e) go to TGS REP to get TICKET_V