# Assignment07 - Amazon Fine Food Reviews Analysis_SVM

June 10, 2019

## 1 Amazon Fine Food Reviews Analysis

Data Source: https://www.kaggle.com/snap/amazon-fine-food-reviews
EDA: https://nycdatascience.com/blog/student-works/amazon-fine-foods-visualization/
The Amazon Fine Food Reviews dataset consists of reviews of fine foods from Amazon.
Number of reviews: 568,454 Number of users: 256,059 Number of products: 74,258 Timespan: Oct 1999 - Oct 2012 Number of Attributes/Columns in data: 10
Attribute Information:

1. Id
2. ProductId - unique identifier for the product
3. UserId - unqiue identifier for the user
4. ProfileName
5. HelpfulnessNumerator - number of users who found the review helpful
6. HelpfulnessDenominator - number of users who indicated whether they found the review helpful or not
7. Score - rating between 1 and 5
8. Time - timestamp for the review
9. Summary - brief summary of the review
10. Text - text of the review

**Objective:** Given a review, determine whether the review is positive (rating of 4 or 5) or negative (rating of 1 or 2).

[Q] How to determine if a review is positive or negative? [Ans] We could use Score/Rating. A rating of 4 or 5 can be cosnidered as a positive review. A rating of 1 or 2 can be considered as negative one. A review of rating 3 is considered nuetral and such reviews are ignored from our analysis. This is an approximate and proxy way of determining the polarity (positivity/negativity) of a review.

## 2 [1]. Reading Data

### 2.1 [1.1] Loading the data

The dataset is available in two forms 1. .csv file 2. SQLite Database

In order to load the data, We have used the SQLITE dataset as it is easier to query the data and visualise the data efficiently.

Here as we only want to get the global sentiment of the recommendations (positive or negative), we will purposefully ignore all Scores equal to 3. If the score is above 3, then the recommendation wil be set to "positive". Otherwise, it will be set to "negative".

In [1]:
```
%matplotlib inline
import warnings
warnings.filterwarnings("ignore")


import sqlite3
import pandas as pd
import numpy as np
import nltk
import string
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.feature_extraction.text import TfidfTransformer
from sklearn.feature_extraction.text import TfidfVectorizer

from sklearn.feature_extraction.text import CountVectorizer
from sklearn.metrics import confusion_matrix
from sklearn import metrics
from sklearn.metrics import roc_curve, auc
from nltk.stem.porter import PorterStemmer

import re
# Tutorial about Python regular expressions: https://pymotw.com/2/re/
import string
from nltk.corpus import stopwords
from nltk.stem import PorterStemmer
from nltk.stem.wordnet import WordNetLemmatizer

from gensim.models import Word2Vec
from gensim.models import KeyedVectors
import pickle

from tqdm import tqdm
import os
```

In [2]:
```
# using SQLite Table to read data.
db_path = '/home/monodeepdas112/Datasets/amazon-fine-food-reviews/database.sqlite'
# db_path = '/home/monodeepdas112/Datasets/AmazonFineFoodReviews/database.sqlite'
con = sqlite3.connect(db_path)

# filtering only positive and negative reviews i.e.
# not taking into consideration those reviews with Score=3
# SELECT * FROM Reviews WHERE Score != 3 LIMIT 500000, will give top 500000 data point
# you can change the number to any other number based on your computing power
```

```
filtered_data = pd.read_sql_query(""" SELECT * FROM Reviews WHERE Score != 3 LIMIT 100
# for tsne assignment you can take 5k data points

# filtered_data = pd.read_sql_query(""" SELECT * FROM Reviews WHERE Score != 3 LIMIT 5

# Give reviews with Score>3 a positive rating(1), and reviews with a score<3 a negativ
def partition(x):
    if x < 3:
        return 0
    return 1

#changing reviews with score less than 3 to be positive and vice-versa
actualScore = filtered_data['Score']
positiveNegative = actualScore.map(partition)
filtered_data['Score'] = positiveNegative
print("Number of data points in our data", filtered_data.shape)
filtered_data.head(3)
```

```
Number of data points in our data (100000, 10)
```

Out[2]:

| | Id | ProductId | UserId | ProfileName | \ |
|---|---|---|---|---|---|
| 0 | 1 | B001E4KFG0 | A3SGXH7AUHU8GW | delmartian | |
| 1 | 2 | B00813GRG4 | A1D87F6ZCVE5NK | dll pa | |
| 2 | 3 | B000LQOCH0 | ABXLMWJIXXAIN | Natalia Corres "Natalia Corres" | |

| | HelpfulnessNumerator | HelpfulnessDenominator | Score | Time | \ |
|---|---|---|---|---|---|
| 0 | 1 | 1 | 1 | 1303862400 | |
| 1 | 0 | 0 | 0 | 1346976000 | |
| 2 | 1 | 1 | 1 | 1219017600 | |

| | Summary | Text |
|---|---|---|
| 0 | Good Quality Dog Food | I have bought several of the Vitality canned d... |
| 1 | Not as Advertised | Product arrived labeled as Jumbo Salted Peanut... |
| 2 | "Delight" says it all | This is a confection that has been around a fe... |

In [3]:
```
display = pd.read_sql_query("""
SELECT UserId, ProductId, ProfileName, Time, Score, Text, COUNT(*)
FROM Reviews
GROUP BY UserId
HAVING COUNT(*)>1
""", con)
```

In [4]:
```
print(display.shape)
display.head()
```

```
(80668, 7)
```

Out[4]:

| | UserId | ProductId | ProfileName | Time | Score | Text | COUNT(*) |
|---|---|---|---|---|---|---|---|
| 0 | #oc-R115TNMSPFT9I7 | B007Y59HVM | Breyton | 1331510400 | 2 | Overall its just OK when considering the price... | 2 |
| 1 | #oc-R11D9D7SHXIJB9 | B005HG9ET0 | Louis E. Emory "hoppy" | 1342396800 | 5 | My wife has recurring extreme muscle spasms, u... | 3 |
| 2 | #oc-R11DNU2NBKQ23Z | B007Y59HVM | Kim Cieszykowski | 1348531200 | 1 | This coffee is horrible and unfortunately not ... | 2 |
| 3 | #oc-R11O5J5ZVQE25C | B005HG9ET0 | Penguin Chick | 1346889600 | 5 | This will be the bottle that you grab from the... | 3 |
| 4 | #oc-R12KPBODL2B5ZD | B007OSBE1U | Christopher P. Presta | 1348617600 | 1 | I didnt like this coffee. Instead of telling y... | 2 |

In [5]:
```
display[display['UserId']=='AZY10LLTJ71NX']
```

Out[5]:

| | UserId | ProductId | ProfileName | Time | Score | Text | COUNT(*) |
|---|---|---|---|---|---|---|---|
| 80638 | AZY10LLTJ71NX | B006P7E5ZI | undertheshrine "undertheshrine" | 1334707200 | 5 | I was recommended to try green tea extract to ... | 5 |

In [6]:
```
display['COUNT(*)'].sum()
```

Out[6]: 393063

# 3 [2] Exploratory Data Analysis

## 3.1 [2.1] Data Cleaning: Deduplication

It is observed (as shown in the table below) that the reviews data had many duplicate entries. Hence it was necessary to remove duplicates in order to get unbiased results for the analysis of the data. Following is an example:

In [7]:
```
display= pd.read_sql_query("""
SELECT *
FROM Reviews
WHERE Score != 3 AND UserId="AR5J8UI46CURR"
ORDER BY ProductID
""", con)
display.head()
```

Out[7]:

| | Id | ProductId | UserId | ProfileName | HelpfulnessNumerator | HelpfulnessDenominator | Score | Time | Summary | Text |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 78445 | B000HDL1RQ | AR5J8UI46CURR | Geetha Krishnan | 2 | 2 | 5 | 1399507200 | LOVE IT | I bought this 6 pack because my dog is allergi... |
| 1 | 138317 | B000HDOPYC | AR5J8UI46CURR | Geetha Krishnan | 2 | 2 | 5 | 1399507200 | LOVE IT | I bought this 6 pack because my dog is allergi... |
| 2 | 138277 | B000HDOPYM | AR5J8UI46CURR | Geetha Krishnan | 2 | 2 | 5 | 1399507200 | LOVE IT | I bought this 6 pack because my dog is allergi... |
| 3 | 73791 | B000HDOPZG | AR5J8UI46CURR | Geetha Krishnan | 2 | 2 | 5 | 1399507200 | LOVE IT | I bought this 6 pack because my dog is allergi... |
| 4 | 155049 | B000PAQ75C | AR5J8UI46CURR | Geetha Krishnan | 2 | 2 | 5 | 1399507200 | LOVE IT | I bought this 6 pack because my dog is allergi... |

```
   HelpfulnessDenominator  Score        Time  \
0                       2      5  1199577600
1                       2      5  1199577600
2                       2      5  1199577600
3                       2      5  1199577600
4                       2      5  1199577600

                            Summary  \
0  LOACKER QUADRATINI VANILLA WAFERS
1  LOACKER QUADRATINI VANILLA WAFERS
2  LOACKER QUADRATINI VANILLA WAFERS
3  LOACKER QUADRATINI VANILLA WAFERS
4  LOACKER QUADRATINI VANILLA WAFERS

                                                Text
0  DELICIOUS WAFERS. I FIND THAT EUROPEAN WAFERS ...
1  DELICIOUS WAFERS. I FIND THAT EUROPEAN WAFERS ...
2  DELICIOUS WAFERS. I FIND THAT EUROPEAN WAFERS ...
3  DELICIOUS WAFERS. I FIND THAT EUROPEAN WAFERS ...
4  DELICIOUS WAFERS. I FIND THAT EUROPEAN WAFERS ...
```

As it can be seen above that same user has multiple reviews with same values for HelpfulnessNumerator, HelpfulnessDenominator, Score, Time, Summary and Text and on doing analysis it was found that ProductId=B000HDOPZG was Loacker Quadratini Vanilla Wafer Cookies, 8.82-Ounce Packages (Pack of 8) ProductId=B000HDL1RQ was Loacker Quadratini Lemon Wafer Cookies, 8.82-Ounce Packages (Pack of 8) and so on

It was inferred after analysis that reviews with same parameters other than ProductId belonged to the same product just having different flavour or quantity. Hence in order to reduce redundancy it was decided to eliminate the rows having same parameters.

The method used for the same was that we first sort the data according to ProductId and then just keep the first similar product review and delelte the others. for eg. in the above just the review for ProductId=B000HDL1RQ remains. This method ensures that there is only one representative for each product and deduplication without sorting would lead to possibility of different representatives still existing for the same product.

```
In [8]: #Sorting data according to ProductId in ascending order
        sorted_data=filtered_data.sort_values('ProductId', axis=0, ascending=True, inplace=Fals

In [9]: #Deduplication of entries
        final=sorted_data.drop_duplicates(subset={"UserId","ProfileName","Time","Text"}, keep=
        final.shape

Out[9]: (87775, 10)

In [10]: #Checking to see how much % of data still remains
         (final['Id'].size*1.0)/(filtered_data['Id'].size*1.0)*100

Out[10]: 87.775
```

Observation:- It was also seen that in two rows given below the value of HelpfulnessNumerator is greater than HelpfulnessDenominator which is not practically possible hence these two rows too are removed from calcualtions

```
In [11]: display= pd.read_sql_query("""
         SELECT *
         FROM Reviews
         WHERE Score != 3 AND Id=44737 OR Id=64422
         ORDER BY ProductID
         """, con)

         display.head()
```

Out[11]:

| | Id | ProductId | UserId | ProfileName | HelpfulnessNumerator | HelpfulnessDenominator | Score | Time | Summary | Text |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 64422 | B000MIDROQ | A161DK06JJMCYF | J. E. Stephens "Jeanne" | 3 | 1 | 5 | 1224892800 | Bought This for My Son at College | My son loves spaghetti so I didn't hesitate or... |
| 1 | 44737 | B001EQ55RW | A2V0I904FH7ABY | Ram | 3 | 2 | 4 | 1212883200 | Pure cocoa taste with crunchy almonds inside | It was almost a 'love at first bite' - the per... |

```
In [12]: final=final[final.HelpfulnessNumerator<=final.HelpfulnessDenominator]

In [13]: #Before starting the next phase of preprocessing lets see the number of entries left
         print(final.shape)

         #How many positive and negative reviews are present in our dataset?
         final['Score'].value_counts()
```

```
(87773, 10)
```

Out[13]:

```
1    73592
0    14181
Name: Score, dtype: int64
```

# 4 [3] Preprocessing

## 4.1 [3.1]. Preprocessing Review Text

Now that we have finished deduplication our data requires some preprocessing before we go on further with analysis and making the prediction model.

Hence in the Preprocessing phase we do the following in the order below:-

1. Begin by removing the html tags
2. Remove any punctuations or limited set of special characters like , or . or # etc.
3. Check if the word is made up of english letters and is not alpha-numeric
4. Check to see if the length of the word is greater than 2 (as it was researched that there is no adjective in 2-letters)
5. Convert the word to lowercase
6. Remove Stopwords
7. Finally Snowball Stemming the word (it was obsereved to be better than Porter Stemming)

After which we collect the words used to describe positive and negative reviews

```
In [14]: # printing some random reviews
         sent_0 = final['Text'].values[0]
         print(sent_0)
         print("="*50)

         sent_1000 = final['Text'].values[1000]
         print(sent_1000)
         print("="*50)

         sent_1500 = final['Text'].values[1500]
         print(sent_1500)
         print("="*50)

         sent_4900 = final['Text'].values[4900]
         print(sent_4900)
         print("="*50)
```

```
My dogs loves this chicken but its a product from China, so we wont be buying it anymore.  Its
==================================================
The Candy Blocks were a nice visual for the Lego Birthday party but the candy has little taste
==================================================
was way to hot for my blood, took a bite and did a jig  lol
==================================================
My dog LOVES these treats. They tend to have a very strong fish oil smell. So if you are afrai
==================================================
```

```
In [15]: # remove urls from text python: https://stackoverflow.com/a/40823105/4084039
         sent_0 = re.sub(r"http\S+", "", sent_0)
         sent_1000 = re.sub(r"http\S+", "", sent_1000)
         sent_150 = re.sub(r"http\S+", "", sent_1500)
         sent_4900 = re.sub(r"http\S+", "", sent_4900)

         print(sent_0)
```

```
My dogs loves this chicken but its a product from China, so we wont be buying it anymore.  Its
```

In [16]:
```
# https://stackoverflow.com/questions/16206380/python-beautifulsoup-how-to-remove-all
from bs4 import BeautifulSoup

soup = BeautifulSoup(sent_0, 'lxml')
text = soup.get_text()
print(text)
print("="*50)

soup = BeautifulSoup(sent_1000, 'lxml')
text = soup.get_text()
print(text)
print("="*50)

soup = BeautifulSoup(sent_1500, 'lxml')
text = soup.get_text()
print(text)
print("="*50)

soup = BeautifulSoup(sent_4900, 'lxml')
text = soup.get_text()
print(text)
```

```
My dogs loves this chicken but its a product from China, so we wont be buying it anymore.  Its
==================================================
The Candy Blocks were a nice visual for the Lego Birthday party but the candy has little taste
==================================================
was way to hot for my blood, took a bite and did a jig  lol
==================================================
My dog LOVES these treats. They tend to have a very strong fish oil smell. So if you are afrai
```

In [17]:
```
# https://stackoverflow.com/a/47091490/4084039
import re

def decontracted(phrase):
    # specific
    phrase = re.sub(r"won't", "will not", phrase)
    phrase = re.sub(r"can\'t", "can not", phrase)

    # general
    phrase = re.sub(r"n\'t", " not", phrase)
    phrase = re.sub(r"\'re", " are", phrase)
    phrase = re.sub(r"\'s", " is", phrase)
    phrase = re.sub(r"\'d", " would", phrase)
    phrase = re.sub(r"\'ll", " will", phrase)
    phrase = re.sub(r"\'t", " not", phrase)
    phrase = re.sub(r"\'ve", " have", phrase)
    phrase = re.sub(r"\'m", " am", phrase)
    return phrase
```

```
In [18]: sent_1500 = decontracted(sent_1500)
         print(sent_1500)
         print("="*50)
```

```
was way to hot for my blood, took a bite and did a jig  lol
==================================================
```

```
In [19]: #remove words with numbers python: https://stackoverflow.com/a/18082370/4084039
         sent_0 = re.sub("\S*\d\S*", "", sent_0).strip()
         print(sent_0)
```

```
My dogs loves this chicken but its a product from China, so we wont be buying it anymore.  Its
```

```
In [20]: #remove spacial character: https://stackoverflow.com/a/5843547/4084039
         sent_1500 = re.sub('[^A-Za-z0-9]+', ' ', sent_1500)
         print(sent_1500)
```

```
was way to hot for my blood took a bite and did a jig lol
```

```
In [21]: # https://gist.github.com/sebleier/554280
         # we are removing the words from the stop words list: 'no', 'nor', 'not'
         # <br /><br /> ==> after the above steps, we are getting "br br"
         # we are including them into stop words list
         # instead of <br /> if we have <br/> these tags would have revmoved in the 1st step

         stopwords= set(['br', 'the', 'i', 'me', 'my', 'myself', 'we', 'our', 'ours', 'ourselve
                     "you'll", "you'd", 'your', 'yours', 'yourself', 'yourselves', 'he', 'him'
                     'she', "she's", 'her', 'hers', 'herself', 'it', "it's", 'its', 'itself',
                     'theirs', 'themselves', 'what', 'which', 'who', 'whom', 'this', 'that', "t
                     'am', 'is', 'are', 'was', 'were', 'be', 'been', 'being', 'have', 'has', 'h
                     'did', 'doing', 'a', 'an', 'the', 'and', 'but', 'if', 'or', 'because', 'as
                     'at', 'by', 'for', 'with', 'about', 'against', 'between', 'into', 'throug
                     'above', 'below', 'to', 'from', 'up', 'down', 'in', 'out', 'on', 'off', 'o
                     'then', 'once', 'here', 'there', 'when', 'where', 'why', 'how', 'all', 'an
                     'most', 'other', 'some', 'such', 'only', 'own', 'same', 'so', 'than', 'too
                     's', 't', 'can', 'will', 'just', 'don', "don't", 'should', "should've", 'n
                     've', 'y', 'ain', 'aren', "aren't", 'couldn', "couldn't", 'didn', "didn't
                     "hadn't", 'hasn', "hasn't", 'haven', "haven't", 'isn', "isn't", 'ma', 'mig
                     "mustn't", 'needn', "needn't", 'shan', "shan't", 'shouldn', "shouldn't",
                     'won', "won't", 'wouldn', "wouldn't"])
```

```
In [22]: # Combining all the above stundents
         from tqdm import tqdm
         preprocessed_reviews = []
         # tqdm is for printing the status bar
         for sentance in tqdm(final['Text'].values):
```

```
            sentance = re.sub(r"http\S+", "", sentance)
            sentance = BeautifulSoup(sentance, 'lxml').get_text()
            sentance = decontracted(sentance)
            sentance = re.sub("\S*\d\S*", "", sentance).strip()
            sentance = re.sub('[^A-Za-z]+', ' ', sentance)
            # https://gist.github.com/sebleier/554280
            sentance = ' '.join(e.lower() for e in sentance.split() if e.lower() not in stopw
            preprocessed_reviews.append(sentance.strip())
```

```
100%|| 87773/87773 [00:38<00:00, 2283.92it/s]
```

```
In [23]: preprocessed_reviews[1500]
```

```
Out[23]: 'way hot blood took bite jig lol'
```

[3.2] Preprocessing Review Summary

```
In [24]: ## Similartly you can do preprocessing for review summary also.
```

# 5 [4] Featurization

## 5.1 [4.1] BAG OF WORDS

```
In [25]: # #BoW
         # count_vect = CountVectorizer() #in scikit-learn
         # count_vect.fit(preprocessed_reviews)
         # print("some feature names ", count_vect.get_feature_names()[:10])
         # print('='*50)

         # final_counts = count_vect.transform(preprocessed_reviews)
         # print("the type of count vectorizer ",type(final_counts))
         # print("the shape of out text BOW vectorizer ",final_counts.get_shape())
         # print("the number of unique words ", final_counts.get_shape()[1])
```

## 5.2 [4.2] Bi-Grams and n-Grams.

```
In [26]: # #bi-gram, tri-gram and n-gram

         # #removing stop words like "not" should be avoided before building n-grams
         # # count_vect = CountVectorizer(ngram_range=(1,2))
         # # please do read the CountVectorizer documentation http://scikit-learn.org/stable/m

         # # you can choose these numebrs min_df=10, max_features=5000, of your choice
         # count_vect = CountVectorizer(ngram_range=(1,2), min_df=10, max_features=5000)
         # final_bigram_counts = count_vect.fit_transform(preprocessed_reviews)
         # print("the type of count vectorizer ",type(final_bigram_counts))
         # print("the shape of out text BOW vectorizer ",final_bigram_counts.get_shape())
         # print("the number of unique words including both unigrams and bigrams ", final_bigr
```

### 5.3 [4.3] TF-IDF

In [27]:
```
# tf_idf_vect = TfidfVectorizer(ngram_range=(1,2), min_df=10)
# tf_idf_vect.fit(preprocessed_reviews)
# print("some sample features(unique words in the corpus)",tf_idf_vect.get_feature_na
# print('='*50)

# final_tf_idf = tf_idf_vect.transform(preprocessed_reviews)
# print("the type of count vectorizer ",type(final_tf_idf))
# print("the shape of out text TFIDF vectorizer ",final_tf_idf.get_shape())
# print("the number of unique words including both unigrams and bigrams ", final_tf_i
```

### 5.4 [4.4] Word2Vec

In [28]:
```
# # Train your own Word2Vec model using your own text corpus
# i=0
# list_of_sentences=[]
# for sentence in preprocessed_reviews:
#     list_of_sentences.append(sentence.split())
```

In [29]:
```
# # Using Google News Word2Vectors

# # in this project we are using a pretrained model by google
# # its 3.3G file, once you load this into your memory
# # it occupies ~9Gb, so please do this step only if you have >12G of ram
# # we will provide a pickle file wich contains a dict ,
# # and it contains all our courpus words as keys and  model[word] as values
# # To use this code-snippet, download "GoogleNews-vectors-negative300.bin"
# # from https://drive.google.com/file/d/0B7XkCwpI5KDYNlNUTTlSS21pQmM/edit
# # it's 1.9GB in size.


# # http://kavita-ganesan.com/gensim-word2vec-tutorial-starter-code/#.W17SRFAzZPY
# # you can comment this whole cell
# # or change these varible according to your need

# is_your_ram_gt_16g=False
# want_to_use_google_w2v = False
# want_to_train_w2v = True

# if want_to_train_w2v:
#     # min_count = 5 considers only words that occured atleast 5 times
#     w2v_model=Word2Vec(list_of_sentance,min_count=5,size=50, workers=4)
#     print(w2v_model.wv.most_similar('great'))
#     print('='*50)
#     print(w2v_model.wv.most_similar('worst'))

# elif want_to_use_google_w2v and is_your_ram_gt_16g:
#     if os.path.isfile('GoogleNews-vectors-negative300.bin'):
```

```
#         w2v_model=KeyedVectors.load_word2vec_format('GoogleNews-vectors-negative300
#         print(w2v_model.wv.most_similar('great'))
#         print(w2v_model.wv.most_similar('worst'))
#     else:
#         print("you don't have gogole's word2vec file, keep want_to_train_w2v = True
```

In [30]:
```
# w2v_words = list(w2v_model.wv.vocab)
# print("number of words that occured minimum 5 times ",len(w2v_words))
# print("sample words ", w2v_words[0:50])
```

## 5.5 [4.4.1] Converting text into vectors using Avg W2V, TFIDF-W2V

### [4.4.1.1] Avg W2v

In [31]:
```
# # average Word2Vec
# # compute average word2vec for each review.
# sent_vectors = []; # the avg-w2v for each sentence/review is stored in this list
# for sent in tqdm(list_of_sentance): # for each review/sentence
#     sent_vec = np.zeros(50) # as word vectors are of zero length 50, you might need
#     cnt_words =0; # num of words with a valid vector in the sentence/review
#     for word in sent: # for each word in a review/sentence
#         if word in w2v_words:
#             vec = w2v_model.wv[word]
#             sent_vec += vec
#             cnt_words += 1
#     if cnt_words != 0:
#         sent_vec /= cnt_words
#     sent_vectors.append(sent_vec)
# print(len(sent_vectors))
# print(len(sent_vectors[0]))
```

### [4.4.1.2] TFIDF weighted W2v

In [32]:
```
# # S = ["abc def pqr", "def def def abc", "pqr pqr def"]
# model = TfidfVectorizer()
# tf_idf_matrix = model.fit_transform(preprocessed_reviews)
# # we are converting a dictionary with word as a key, and the idf as a value
# dictionary = dict(zip(model.get_feature_names(), list(model.idf_)))
```

In [33]:
```
# # TF-IDF weighted Word2Vec
# tfidf_feat = model.get_feature_names() # tfidf words/col-names
# # final_tf_idf is the sparse matrix with row= sentence, col=word and cell_val = tfi

# tfidf_sent_vectors = []; # the tfidf-w2v for each sentence/review is stored in this
# row=0;
# for sent in tqdm(list_of_sentance): # for each review/sentence
#     sent_vec = np.zeros(50) # as word vectors are of zero length
#     weight_sum =0; # num of words with a valid vector in the sentence/review
#     for word in sent: # for each word in a review/sentence
```

```
#         if word in w2v_words and word in tfidf_feat:
#             vec = w2v_model.wv[word]
# #             tf_idf = tf_idf_matrix[row, tfidf_feat.index(word)]
#             # to reduce the computation we are
#             # dictionary[word] = idf value of word in whole courpus
#             # sent.count(word) = tf valeus of word in this review
#             tf_idf = dictionary[word]*(sent.count(word)/len(sent))
#             sent_vec += (vec * tf_idf)
#             weight_sum += tf_idf
#     if weight_sum != 0:
#         sent_vec /= weight_sum
#     tfidf_sent_vectors.append(sent_vec)
#     row += 1
```

## 6 [5] Assignment 7: SVM

```
<li><strong>Apply SVM on these feature sets</strong>
    <ul>
        <li><font color='red'>SET 1:</font>Review text, preprocessed one converted into vectors
        <li><font color='red'>SET 2:</font>Review text, preprocessed one converted into vectors
        <li><font color='red'>SET 3:</font>Review text, preprocessed one converted into vectors
        <li><font color='red'>SET 4:</font>Review text, preprocessed one converted into vectors
    </ul>
</li>
<br>
<li><strong>Procedure</strong>
    <ul>
<li>You need to work with 2 versions of SVM
    <ul><li>Linear kernel</li>
        <li>RBF kernel</li></ul>
<li>When you are working with linear kernel, use SGDClassifier with hinge loss because it is co
<li>When you are working with SGDClassifier with hinge loss and trying to find the AUC
    score, you would have to use <a href='https://scikit-learn.org/stable/modules/generated/skl
<li>Similarly, like kdtree of knn, when you are working with RBF kernel it's better to reduce
```

the number of dimensions. You can put min_df = 10, max_features = 500 and consider a sample size of 40k points.

```
    </ul>
</li>
<br>
<li><strong>Hyper paramter tuning (find best alpha in range [10^-4 to 10^4], and the best penal
    <ul>
<li>Find the best hyper parameter which will give the maximum <a href='https://www.appliedaicou
<li>Find the best hyper paramter using k-fold cross validation or simple cross validation data
<li>Use gridsearch cv or randomsearch cv or you can also write your own for loops to do this ta
    </ul>
</li>
```

```
<br>
<li><strong>Feature importance</strong>
    <ul>
<li>When you are working on the linear kernel with BOW or TFIDF please print the top 10 best
```

features for each of the positive and negative classes.

```
    </ul>
</li>
<br>
<li><strong>Feature engineering</strong>
    <ul>
<li>To increase the performance of your model, you can also experiment with with feature engine
        <ul>
        <li>Taking length of reviews as another feature.</li>
        <li>Considering some features from review summary as well.</li>
    </ul>
    </ul>
</li>
<br>
<li><strong>Representation of results</strong>
    <ul>
<li>You need to plot the performance of model both on train data and cross validation data for
<img src='train_cv_auc.JPG' width=300px></li>
<li>Once after you found the best hyper parameter, you need to train your model with it, and fi
<img src='train_test_auc.JPG' width=300px></li>
<li>Along with plotting ROC curve, you need to print the <a href='https://www.appliedaicourse.c
<img src='confusion_matrix.png' width=300px></li>
    </ul>
</li>
<br>
<li><strong>Conclusion</strong>
    <ul>
<li>You need to summarize the results at the end of the notebook, summarize it in the table for
    <img src='summary.JPG' width=400px>
</li>
    </ul>
```

Note: Data Leakage

1. There will be an issue of data-leakage if you vectorize the entire data and then split it into train/cv/test.
2. To avoid the issue of data-leakag, make sure to split your data first and then vectorize it.
3. While vectorizing your data, apply the method fit_transform() on you train data, and apply the method transform() on cv/test data.
4. For more details please go through this link.

# 7 Applying SVM

```
In [34]: from sklearn.linear_model import SGDClassifier
         from sklearn.svm import SVC
         from sklearn.calibration import CalibratedClassifierCV
         from sklearn.metrics import confusion_matrix
         from sklearn.metrics import roc_curve, auc
         from sklearn.metrics import roc_auc_score
         from sklearn.model_selection import train_test_split
         from sklearn.model_selection import StratifiedKFold
         import pprint
         from sklearn.pipeline import Pipeline
         import os.path
         import pickle
         import math

         import warnings
         warnings.filterwarnings('ignore')
```

### 7.0.1 [5.0.0] Splitting up the Dataset into D_train and D_test

```
In [35]: num_data_points = 100000
```

```
In [36]: Dx_train, Dx_test, Dy_train, Dy_test = train_test_split(preprocessed_reviews[:num_data
```

```
In [37]: prettytable_data = []
```

### 7.0.2 [5.0.1] Defining some functions to increase code reusability and readability

```
In [38]: '''Creating Custom Vectorizers for TFIDF - W2Vec and Avg - W2Vec'''
         class Tfidf_W2Vec_Vectorizer(object):
             def __init__(self, w2vec_model):
                 if(w2v_model is None):
                     raise Exception('Word 2 Vector model passed to Tfidf_W2Vec Vectorizer is N
                 self.tfidf = TfidfVectorizer(max_features=300)
                 self.dictionary = None
                 self.tfidf_feat = None

                 self.word2vec = w2vec_model

             def fit(self, X):
                 '''X : list'''
                 #Initializing the TFIDF Vectorizer
                 self.tfidf.fit_transform(X)
                 # we are converting a dictionary with word as a key, and the idf as a value
                 self.dictionary = dict(zip(self.tfidf.get_feature_names(), list(self.tfidf.idf
                 self.tfidf_feat = self.tfidf.get_feature_names()

                 return self
```

```
            def transform(self, X):
                '''X : list'''
                return np.array([
                        np.mean([self.word2vec[w] * self.dictionary[word]*(X.cout(word)/len(X)
                                 for w in words if w in self.word2vec and w in self.tfidf_feat
                                [np.zeros(300)], axis=0)
                                for words in X
                    ])

        class Avg_W2Vec_Vectorizer(object):
            def __init__(self, w2vec_model):
                if(w2v_model is None):
                    raise Exception('Word 2 Vector model passed to Avg_W2Vec Vectorizer is Nor
                self.word2vec = w2vec_model

            def fit(self, X):
                return self

            def transform(self, X):
                '''X : list'''
                return np.array([
                    np.mean([self.word2vec[w] for w in words if w in self.word2vec]
                            or [np.zeros(300)], axis=0)
                    for words in X
                ])

In [39]: def get_vectorizer(vectorizer, train, W2V_model=None):
            if(vectorizer=='BOW'):
                vectorizer = CountVectorizer(ngram_range=(1,2), min_df=10, max_features=5000)
            if(vectorizer=='TFIDF'):
                vectorizer = TfidfVectorizer(ngram_range=(1,2), min_df=10, max_features=5000)
            if(vectorizer=='TFIDF-W2Vec'):
                vectorizer = Tfidf_W2Vec_Vectorizer(W2V_model)
            if(vectorizer=='Avg-W2Vec'):
                vectorizer = Avg_W2Vec_Vectorizer(W2V_model)

            vectorizer.fit(train)
            return vectorizer

In [40]: '''Perform Simple Cross Validation'''
        def perform_hyperparameter_tuning(X, Y, vectorizer, penalty, results_path, retrain=Fal
            #If the pandas dataframe with the hyperparameter info exists then return it

            if(retrain==False):
                # If Cross Validation results exists then return them
                if(os.path.exists(results_path)):
                    return pd.read_csv(results_path)
```

```
        else:
            # If no data exists but retrain=False then mention accordingly
            print('Retrain is set to be False but no Cross Validation Results DataFra
    else:
        # else perform hyperparameter tuning
        print('Performing Hyperparameter Tuning...\n')
        # regularization parameter
        alpha = [0.0001, 0.0005, 0.001, 0.005, 0.01, 0.05, 0.1, 0.5, 1, 5, 10, 50, 10
        hyperparameters = {
            'svm__penalty' : penalty,
            'svm__alpha' : alpha
        }

        penalties = []
        alpha_values = []

        train_scores = []
        test_scores = []

        train_mean_score = []
        test_mean_score = []

        # Initializing KFold
        skf = StratifiedKFold(n_splits=3)
        X = np.array(X)
        Y = np.array(Y)

        for reg_param in hyperparameters['svm__alpha']:
            for penalty in hyperparameters['svm__penalty']:

                #Performing Cross Validation
                for train_index, test_index in skf.split(X, Y):
                    Dx_train, Dx_cv = X[train_index], X[test_index]
                    Dy_train, Dy_cv = Y[train_index], Y[test_index]

                    #Initializing the Vectorizer
                    vectorizer = get_vectorizer(vectorizer, Dx_train.tolist(), W2V_mo

                    #Transforming the data to features
                    x_train = vectorizer.transform(Dx_train.tolist())
                    x_cv = vectorizer.transform(Dx_cv.tolist())

                    #Initializing the LR model
                    svm = SGDClassifier(penalty=penalty,
                                        alpha=reg_param,
                                        max_iter=1000, verbose=0)

                    # Fit the model
```

```
                svm.fit(x_train, Dy_train)

                # Calibrating the sum model to output probablity class labels
                calib_svm = CalibratedClassifierCV(base_estimator=svm, method="isc
                calib_svm.fit(x_train, Dy_train)

                #Prediction
                train_results = calib_svm.predict_proba(x_train)
                cv_results = calib_svm.predict_proba(x_cv)

                try:
                    train_score = roc_auc_score(Dy_train, train_results[:, 1])
                    test_score = roc_auc_score(Dy_cv, cv_results[:, 1])

                    #storing the results to form a dataframe
                    train_scores.append(train_score)
                    test_scores.append(test_score)

                except Exception as e:
                    print('Error Case : ', e)
                    print(('Actual, Predicted'))
                    [print((Dy_cv[i], cv_results[i, 1])) for i in range(len(Dy_cv)

                print('CV iteration : alpha={0}, penalty={1}, train_score={2}, tes
                  .format(reg_param, penalty, train_score, test_score))

            train_mean_score.append(sum(train_scores)/len(train_scores))
            test_mean_score.append(sum(test_scores)/len(test_scores))

            penalties.append(penalty)
            alpha_values.append(reg_param)

            print('C={0}, penalty={1}, train_score={2}, test_score={3}'
                  .format(reg_param, penalty, sum(train_scores)/len(train_scores)

            train_scores = []
            test_scores = []

    # Creating a DataFrame from the saved data for visualization
    results_df = pd.DataFrame({'alpha' : alpha_values, 'penalty' : penalties,
                               'train_score' : train_mean_score,
                               'test_score': test_mean_score})

    #writing the results to csv after performing hyperparameter tuning
    try:
        results_df.to_csv(results_path)
    except Exception as ex:
        print(str(ex), "\nError occured while converting DataFrame to CSV after cr
```

```
                return results_df

In [41]: def analyse_results(df):
             # plotting error curves
             fig = plt.figure(figsize=(15, 5))
             ax = fig.gca()

             mini = df.loc[df['penalty'] == 'l1']
             plt.subplot(1, 2, 1)
             plt.plot([math.log10(i) for i in mini.alpha.tolist()], mini.train_score.tolist(),
             plt.plot([math.log10(i) for i in mini.alpha.tolist()], mini.test_score.tolist(),
             plt.grid(True)
             plt.xlabel('log10 of Hyperparameter alpha')
             plt.ylabel('Area Under ROC Curve')
             plt.title('AUC ROC Curve : Penalty = '.format('l1'))
             plt.legend(loc='best')

             mini = df.loc[df['penalty'] == 'l2']
             plt.subplot(1, 2, 2)
             plt.plot([math.log10(i) for i in mini.alpha.tolist()], mini.train_score.tolist(),
             plt.plot([math.log10(i) for i in mini.alpha.tolist()], mini.test_score.tolist(),
             plt.grid(True)
             plt.xlabel('log10 of Hyperparameter alpha')
             plt.ylabel('Area Under ROC Curve')
             plt.title('AUC ROC Curve : Penalty = '.format('l2'))
             plt.legend(loc='best')

             plt.show()

             # return the best parameters
             mmax = 0
             ind_max = 0
             for index, row in df.iterrows():
                 if(row['test_score']>mmax):
                     mmax=row['test_score']
                     ind_max = index


             best_params = {
                 'svm__alpha': df.loc[ind_max, 'alpha'],
                 'svm__penalty':df.loc[ind_max, 'penalty']
             }

             return best_params

In [42]: def retrain_with_best_params(data, labels, best_params, vec_name, model_path, word2ve
             if(os.path.exists(model_path)):
                 print('Loading Model....')
```

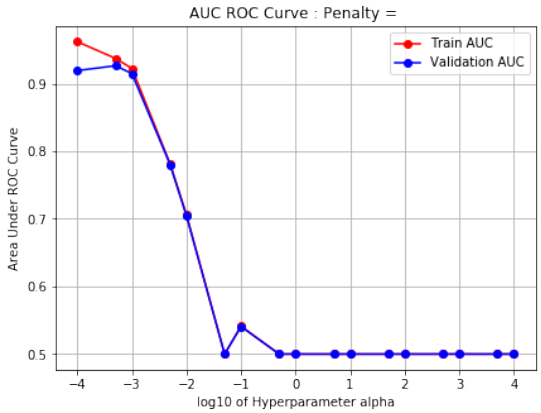
```
            with open(model_path, 'rb') as input_file:
                calib_svm = pickle.load(input_file)
        else:
            svm = SGDClassifier(penalty=best_params['svm__penalty'], alpha=best_params['sv

            print('Initializing Vectorizer')
            vectorizer = get_vectorizer(vectorizer=vec_name, train=data, W2V_model=word2ve
            print('Training Model....')
            svm.fit(vectorizer.transform(data), np.array(labels))

            calib_svm = CalibratedClassifierCV(base_estimator=svm, method="isotonic", cv='
            calib_svm.fit(vectorizer.transform(data), np.array(labels))

            print('Saving Trained Model....')
            with open(model_path,'wb') as file:
                pickle.dump(calib_svm, file)
        return calib_svm

In [43]: def plot_confusion_matrix(model, data, labels, dataset_label):
        pred = model.predict(data)
        conf_mat = confusion_matrix(labels, pred)

        strings = strings = np.asarray([['TN = ', 'FP = '],
                                        ['FN = ', 'TP = ']])

        labels = (np.asarray(["{0}{1}".format(string, value)
                              for string, value in zip(strings.flatten(),
                                                       conf_mat.flatten())])
                  ).reshape(2, 2)

        fig, ax = plt.subplots()
        ax.set(xlabel='Predicted', ylabel='Actual', title='Confusion Matrix : {0}'.format
        sns.heatmap(conf_mat, annot=labels, fmt="", cmap='YlGnBu', ax=ax)
        ax.set_xlabel('Predicted')
        ax.set_ylabel('Actual')
        ax.set_xticklabels(['False', 'True'])
        ax.set_yticklabels(['False', 'True'])
        plt.show()

In [44]: def plot_AUC_ROC(model, vectorizer, Dx_train, Dx_test, Dy_train, Dy_test):

        #predicting probability of Dx_test, Dx_train
        test_score = model.predict_proba(vectorizer.transform(Dx_test))
        train_score = model.predict_proba(vectorizer.transform(Dx_train))

        #Finding out the ROC_AUC_SCORE
        train_roc_auc_score = roc_auc_score(np.array(Dy_train), train_score[:, 1])
        print('Area Under the Curve for Train : ', train_roc_auc_score)
```

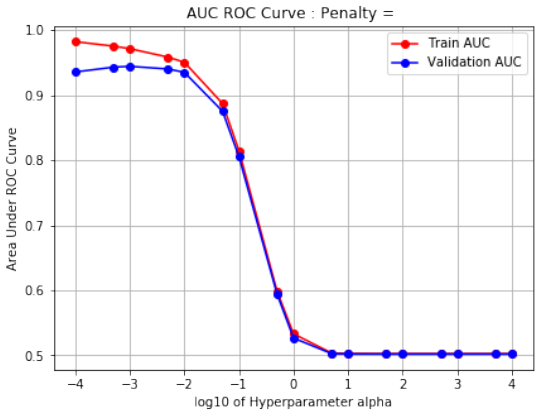
```
    test_roc_auc_score = roc_auc_score(np.array(Dy_test), test_score[:, 1])
    print('Area Under the Curve for Test : ', test_roc_auc_score)

    #Plotting with matplotlib.pyplot
    #ROC Curve for D-train
    train_fpr, train_tpr, thresholds = roc_curve(np.array(Dy_train), train_score[:, 1]
    plt.plot(train_fpr, train_tpr, label="train AUC ="+str(auc(train_fpr, train_tpr)))

    # #ROC Curve for D-test
    test_fpr, test_tpr, thresholds = roc_curve(np.array(Dy_test), test_score[:, 1])
    plt.plot(test_fpr, test_tpr, label="train AUC ="+str(auc(test_fpr, test_tpr)))

    plt.legend()
    plt.xlabel("FPR : False Positive Ratio")
    plt.ylabel("TPF : True Positive Ratio")
    plt.title("Area Under ROC Curve")
    plt.show()

    plot_confusion_matrix(model, vectorizer.transform(Dx_train), np.array(Dy_train),
    plot_confusion_matrix(model, vectorizer.transform(Dx_test), np.array(Dy_test), 'Te
    return train_roc_auc_score, test_roc_auc_score
```

## 7.1 [5.1] Linear SVM

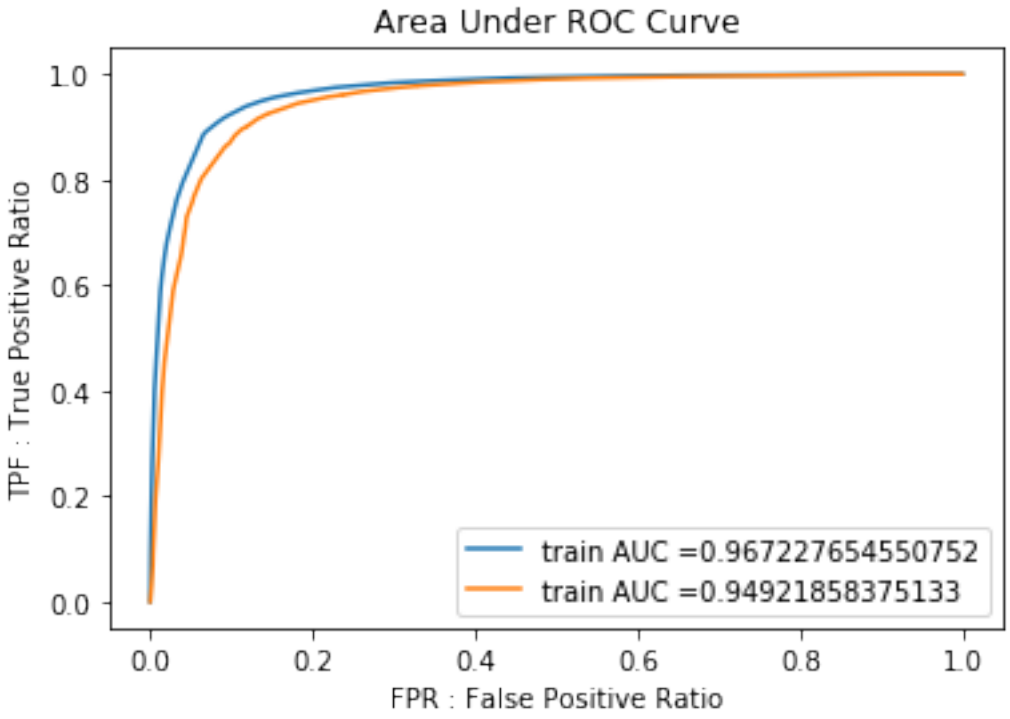
### 7.1.1 [5.1.1] Applying Linear SVM on BOW, SET 1

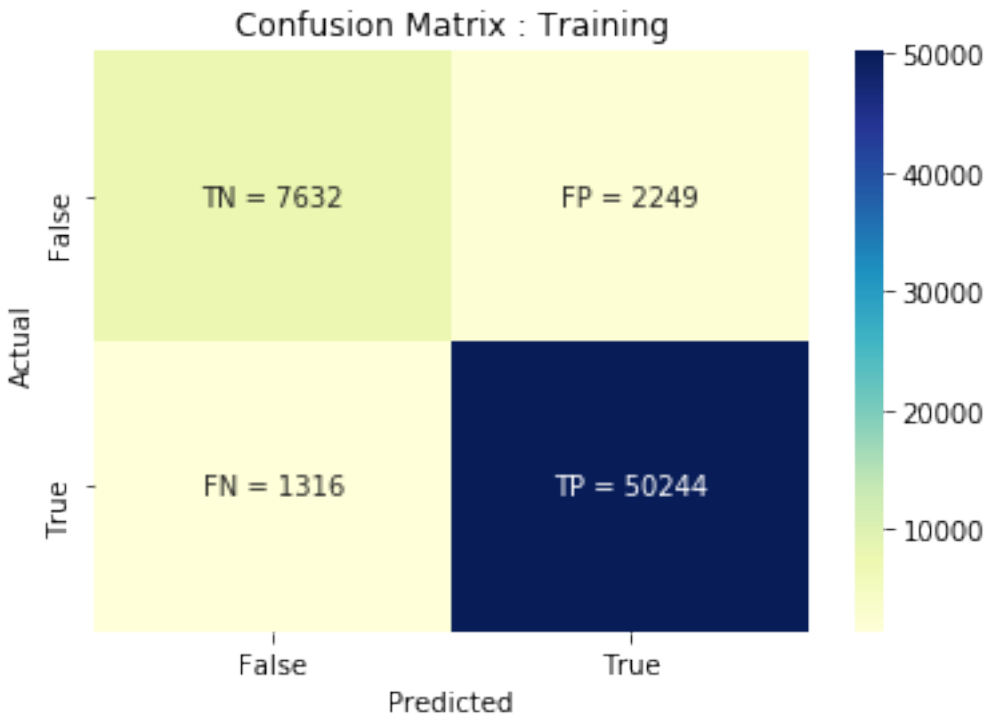
```
In [45]: # Please write all the code with proper documentation
         csv_path = 'saved_models/Assignment7/BOW_svm_results.csv'
         cv_results = perform_hyperparameter_tuning(X=Dx_train, Y=Dy_train, vectorizer='BOW',
                                                    penalty=['l1', 'l2'], results_path=csv_path
         # Analysing best parameters
         best_parameters = analyse_results(cv_results)
         pprint.pprint(best_parameters)
         # retraining the model with best parameters
         model_path = 'saved_models/Assignment7/{0}_svm.pkl'.format('BOW')
         calibrated_svm = retrain_with_best_params(Dx_train, Dy_train, best_parameters, 'BOW',

         print('Retraining Vectorizer with Dx_train')
         vectorizer_obj = get_vectorizer(W2V_model = None, train=Dx_train, vectorizer='BOW')

         # plotting AUC ROC
         train_score, test_score = plot_AUC_ROC(calibrated_svm, vectorizer_obj, Dx_train, Dx_te

         # appending the data results
         prettytable_data.append(['BOW', 'SVM', best_parameters['svm__penalty'], best_parameter
```

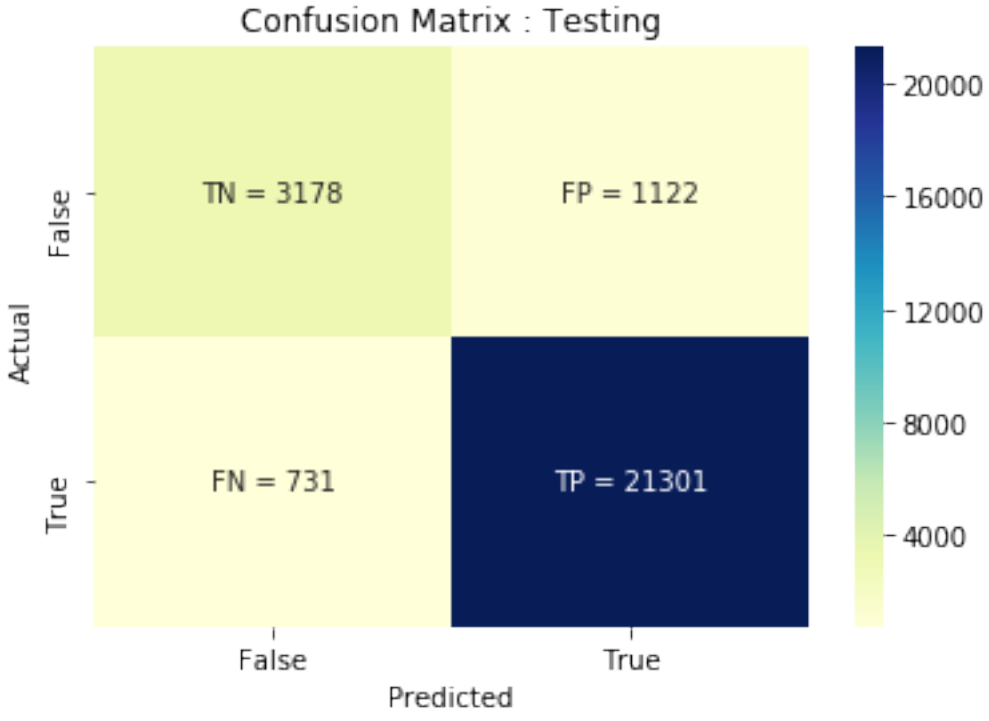



```
{'svm__alpha': 0.001, 'svm__penalty': 'l2'}
Loading Model...
Retraining Vectorizer with Dx_train
Area Under the Curve for Train :  0.967227654550752
Area Under the Curve for Test :  0.94921858375133
```

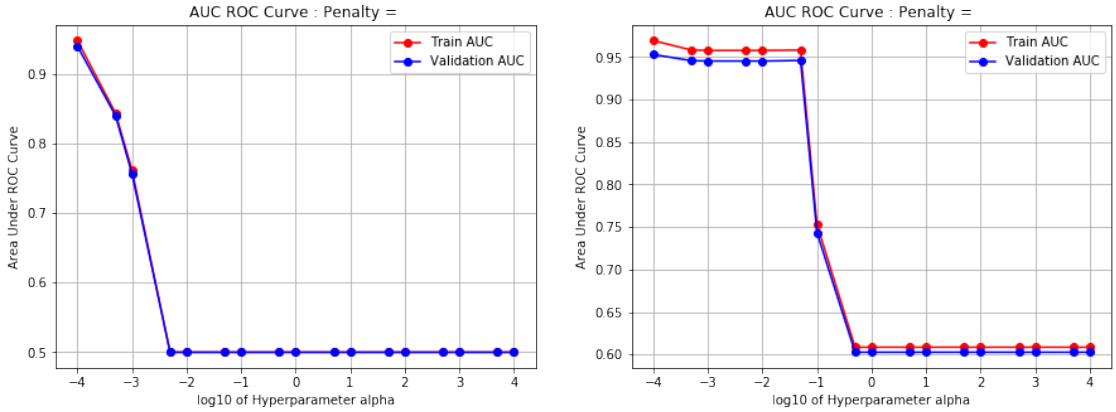



Confusion Matrix : Training
TN = 7632
FP = 2249
FN = 1316
TP = 50244
False
True
Actual
False
True
Predicted
50000
40000
30000
20000
10000

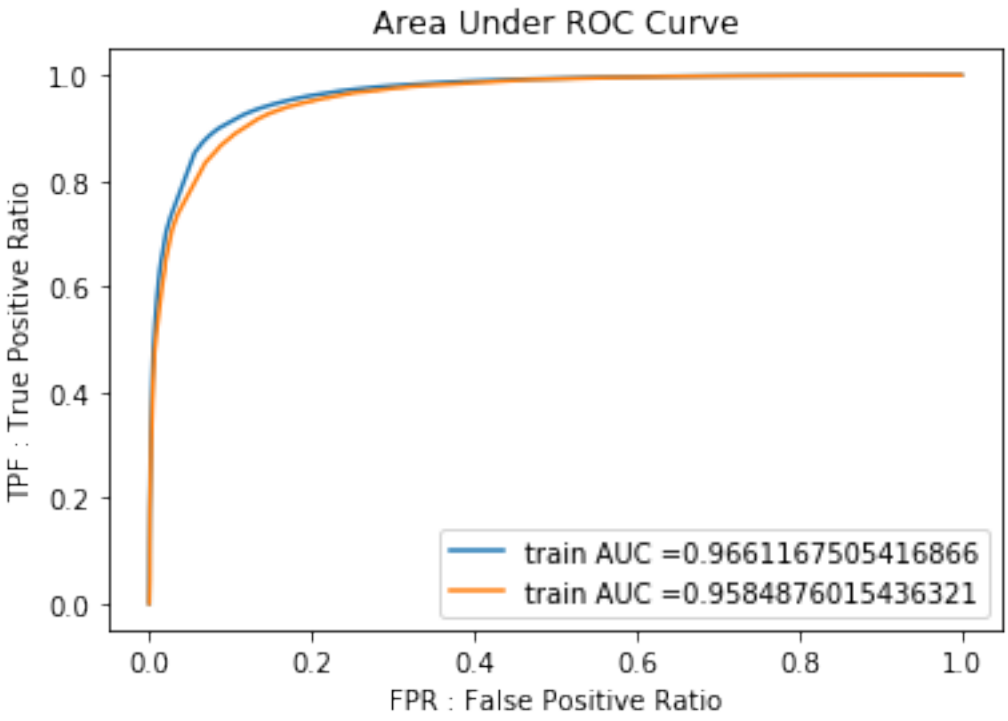

Confusion Matrix : Testing
TN = 3178
FP = 1122
FN = 731
TP = 21301
False
True
Actual
False
True
Predicted
20000
16000
12000
8000
4000

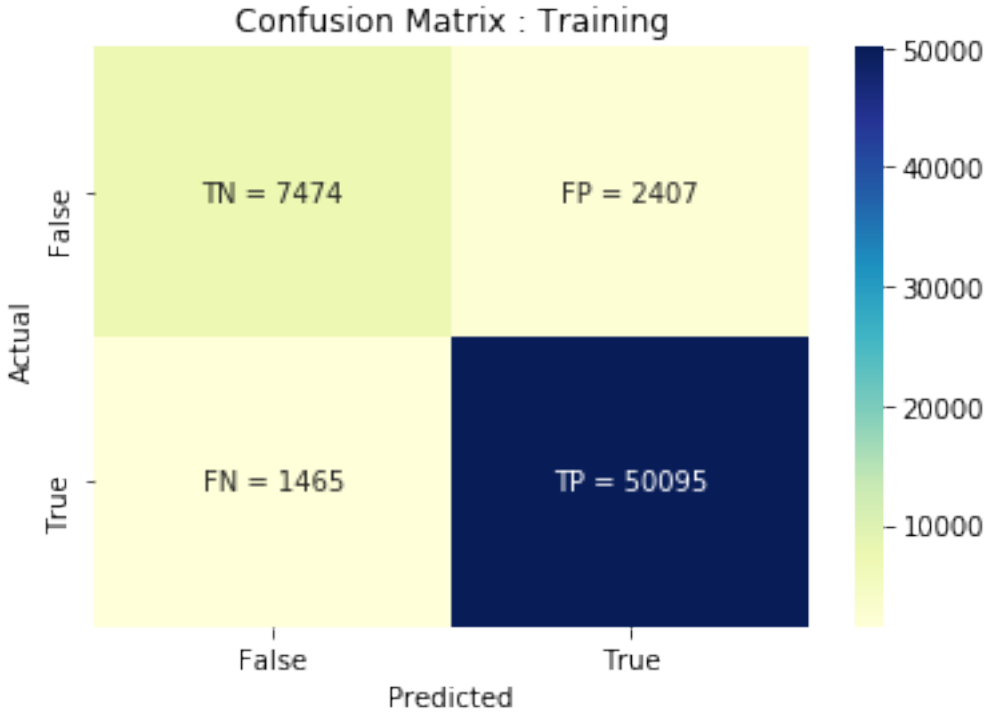
### 7.1.2 [5.1.2] Applying Linear SVM on TFIDF, SET 2

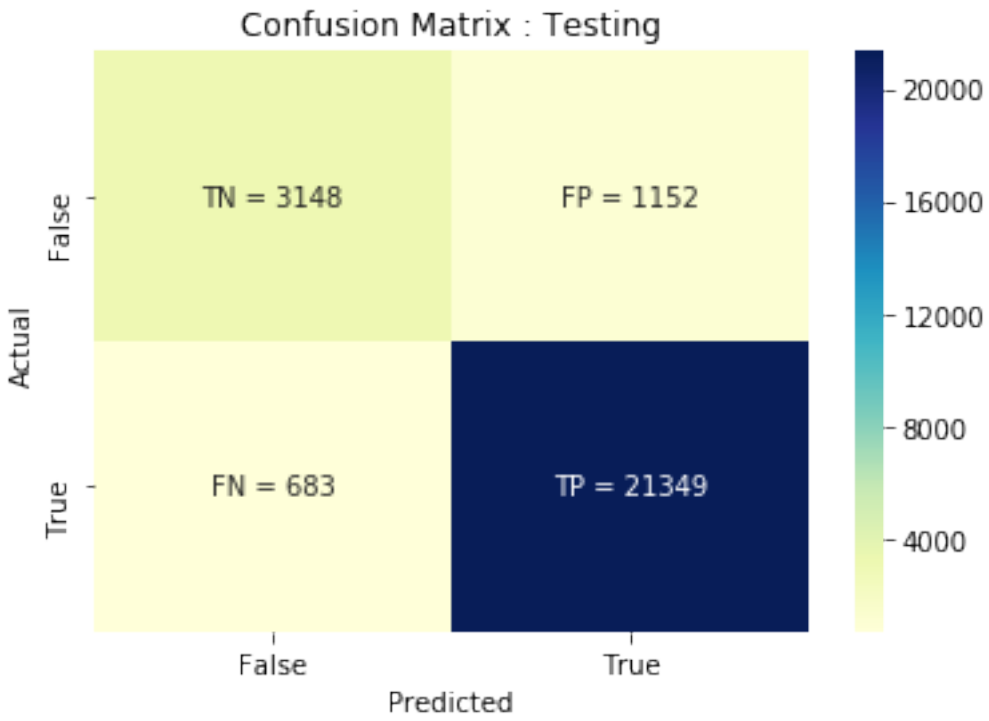
In [46]:
```
# Please write all the code with proper documentation
csv_path = 'saved_models/Assignment7/TFIDF_svm_results.csv'
cv_results = perform_hyperparameter_tuning(X=Dx_train, Y=Dy_train, vectorizer='TFIDF'
                                           penalty=['l1', 'l2'], results_path=csv_pat
# Analysing best parameters
best_parameters = analyse_results(cv_results)
pprint.pprint(best_parameters)
# retraining the model with best parameters
model_path = 'saved_models/Assignment7/{0}_svm.pkl'.format('TFIDF')
calibrated_svm = retrain_with_best_params(Dx_train, Dy_train, best_parameters, 'TFIDF

print('Retraining Vectorizer with Dx_train')
vectorizer_obj = get_vectorizer(W2V_model = None, train=Dx_train, vectorizer='TFIDF')

# plotting AUC ROC
train_score, test_score = plot_AUC_ROC(calibrated_svm, vectorizer_obj, Dx_train, Dx_te

# appending the data results
prettytable_data.append(['TFIDF', 'SVM', best_parameters['svm__penalty'], best_paramet
```




```
{'svm__alpha': 0.0001, 'svm__penalty': 'l2'}
Loading Model...
Retraining Vectorizer with Dx_train
Area Under the Curve for Train :  0.9661167505416866
Area Under the Curve for Test :  0.9584876015436321
```


Area Under ROC Curve
TPF : True Positive Ratio
FPR : False Positive Ratio
train AUC =0.9661167505416866
train AUC =0.9584876015436321
0.0
0.2
0.4
0.6
0.8
1.0


Confusion Matrix : Training
TN = 7474
FP = 2407
FN = 1465
TP = 50095
Actual
False
True
Predicted
50000
40000
30000
20000
10000




## 7.2 Preparing/Training Google Word2Vec

```
In [47]: is_your_ram_gt_16g=True
         want_to_use_google_w2v = False
         want_to_train_w2v = True

         path_to_word2vec = '/home/monodeepdas112/Datasets/GoogleNews-vectors-negative300.bin.g

         if want_to_train_w2v:

             # Train your own Word2Vec model using your own text corpus
             i=0
             list_of_sentences=[]
             for sentance in preprocessed_reviews:
                 list_of_sentences.append(sentance.split())

             # min_count = 5 considers only words that occured atleast 5 times
             w2v_model=Word2Vec(list_of_sentences,min_count=5,size=300, workers=4)
             print(w2v_model.wv.most_similar('great'))
             print('='*50)
             print(w2v_model.wv.most_similar('worst'))

         elif want_to_use_google_w2v and is_your_ram_gt_16g:
```

```
            if os.path.isfile(path_to_word2vec):
                print('Preparing to load pre-trained Word2Vec model !')
                w2v_model=KeyedVectors.load_word2vec_format(path_to_word2vec, binary=True, cla
                print('Successfully loaded model into memory !!!')
                print('Words similar to "similar" : ', w2v_model.wv.most_similar('great'))
                print('Words similar to "worst" : ',w2v_model.wv.most_similar('worst'))
            else:
                print("you don't have google's word2vec file, keep want_to_train_w2v = True, t
```

```
[('fantastic', 0.7747631669044495), ('excellent', 0.7489873766899109), ('awesome', 0.743829965
==================================================
[('greatest', 0.7694377899169922), ('best', 0.675922155380249), ('tastiest', 0.67184978723526)
```

### 7.2.1 [5.1.3] Applying Linear SVM on AVG W2V, SET 3

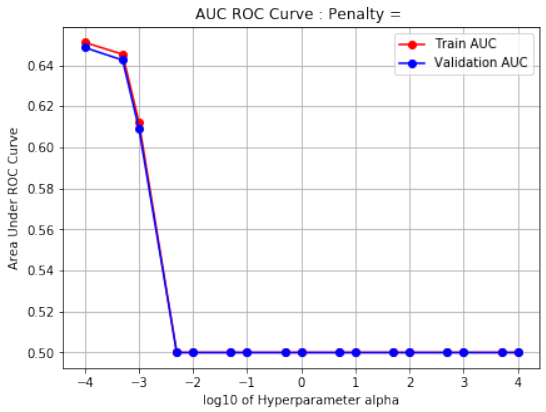
```
In [48]: # Please write all the code with proper documentation
         csv_path = 'saved_models/Assignment7/Avg-W2Vec_svm_results.csv'
         cv_results = perform_hyperparameter_tuning(X=Dx_train, Y=Dy_train, vectorizer='Avg-W2V
                                                    penalty=['l1', 'l2'], results_path=csv_path
                                                    retrain=True, W2V_model=w2v_model)
         # Analysing best parameters
         best_parameters = analyse_results(cv_results)
         pprint.pprint(best_parameters)
         # retraining the model with best parameters
         model_path = 'saved_models/Assignment7/{0}_svm.pkl'.format('Avg-W2Vec')
         calibrated_svm = retrain_with_best_params(Dx_train, Dy_train, best_parameters, 'Avg-W2

         print('Retraining Vectorizer with Dx_train')
         vectorizer_obj = get_vectorizer(W2V_model = w2v_model, train=Dx_train, vectorizer='Avg

         # plotting AUC ROC
         train_score, test_score = plot_AUC_ROC(calibrated_svm, vectorizer_obj, Dx_train, Dx_te

         # appending the data results
         prettytable_data.append(['Avg-W2Vec', 'SVM', best_parameters['svm__penalty'], best_par
```

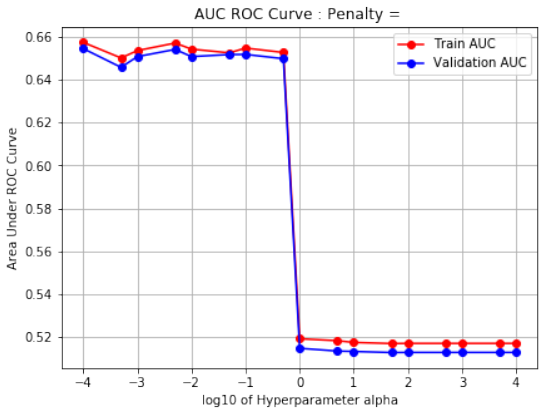
```
Performing Hyperparameter Tuning...

CV iteration : alpha=0.0001, penalty=l1, train_score=0.6482761423294877, test_score=0.643181989
CV iteration : alpha=0.0001, penalty=l1, train_score=0.6535254688194155, test_score=0.651655179
CV iteration : alpha=0.0001, penalty=l1, train_score=0.6515077601506822, test_score=0.650917301
C=0.0001, penalty=l1, train_score=0.6511031237665285, test_score=0.6485848235002699
CV iteration : alpha=0.0001, penalty=l2, train_score=0.6564748566449571, test_score=0.652545737
CV iteration : alpha=0.0001, penalty=l2, train_score=0.6569709038339964, test_score=0.655226594
CV iteration : alpha=0.0001, penalty=l2, train_score=0.6587295852978216, test_score=0.655701481
C=0.0001, penalty=l2, train_score=0.6573917819255916, test_score=0.654491271080013
CV iteration : alpha=0.0005, penalty=l1, train_score=0.6447688430257418, test_score=0.637691234
```

```
CV iteration : alpha=0.0005, penalty=l1, train_score=0.644082885674807, test_score=0.644255231
CV iteration : alpha=0.0005, penalty=l1, train_score=0.6469969704301648, test_score=0.64545582
C=0.0005, penalty=l1, train_score=0.6452828997102379, test_score=0.642467430542314
CV iteration : alpha=0.0005, penalty=l2, train_score=0.6493349416664627, test_score=0.64289297
CV iteration : alpha=0.0005, penalty=l2, train_score=0.6448999849837654, test_score=0.64085273
CV iteration : alpha=0.0005, penalty=l2, train_score=0.6561388646810863, test_score=0.65352909
C=0.0005, penalty=l2, train_score=0.650124597110438, test_score=0.6457562132399928
CV iteration : alpha=0.001, penalty=l1, train_score=0.6115787269719657, test_score=0.599976396
CV iteration : alpha=0.001, penalty=l1, train_score=0.6144236119813483, test_score=0.619410907
CV iteration : alpha=0.001, penalty=l1, train_score=0.6112097925710149, test_score=0.608200106
C=0.001, penalty=l1, train_score=0.612404043841443, test_score=0.6091958034237717
CV iteration : alpha=0.001, penalty=l2, train_score=0.6509494794802663, test_score=0.645657667
CV iteration : alpha=0.001, penalty=l2, train_score=0.6510188476908487, test_score=0.651096589
CV iteration : alpha=0.001, penalty=l2, train_score=0.6587112086523933, test_score=0.655510903
C=0.001, penalty=l2, train_score=0.6535598452745028, test_score=0.650755053597667
CV iteration : alpha=0.005, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.005, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.005, penalty=l1, train_score=0.5, test_score=0.5
C=0.005, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.005, penalty=l2, train_score=0.6568216954895351, test_score=0.652142674
CV iteration : alpha=0.005, penalty=l2, train_score=0.6561139197914541, test_score=0.653775892
CV iteration : alpha=0.005, penalty=l2, train_score=0.6583006629564168, test_score=0.656428199
C=0.005, penalty=l2, train_score=0.6570787594124686, test_score=0.654115588730445
CV iteration : alpha=0.01, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.01, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.01, penalty=l1, train_score=0.5, test_score=0.5
C=0.01, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.01, penalty=l2, train_score=0.6572752874433633, test_score=0.651533257
CV iteration : alpha=0.01, penalty=l2, train_score=0.655597827548058, test_score=0.655068038144
CV iteration : alpha=0.01, penalty=l2, train_score=0.6498634621647679, test_score=0.645666715
C=0.01, penalty=l2, train_score=0.6542455257187297, test_score=0.6507560038402734
CV iteration : alpha=0.05, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.05, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.05, penalty=l1, train_score=0.5, test_score=0.5
C=0.05, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.05, penalty=l2, train_score=0.6544115697553913, test_score=0.652003211
CV iteration : alpha=0.05, penalty=l2, train_score=0.6445712920256755, test_score=0.646206675
CV iteration : alpha=0.05, penalty=l2, train_score=0.6585541471754556, test_score=0.656922805
C=0.05, penalty=l2, train_score=0.6525123363188409, test_score=0.6517108977283793
CV iteration : alpha=0.1, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.1, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.1, penalty=l1, train_score=0.5, test_score=0.5
C=0.1, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.1, penalty=l2, train_score=0.6558269886514694, test_score=0.648387850435
CV iteration : alpha=0.1, penalty=l2, train_score=0.6528481504739498, test_score=0.652054118154
CV iteration : alpha=0.1, penalty=l2, train_score=0.6555419802862112, test_score=0.654900541754
C=0.1, penalty=l2, train_score=0.6547390398038768, test_score=0.6517808367814225
CV iteration : alpha=0.5, penalty=l1, train_score=0.5, test_score=0.5
```

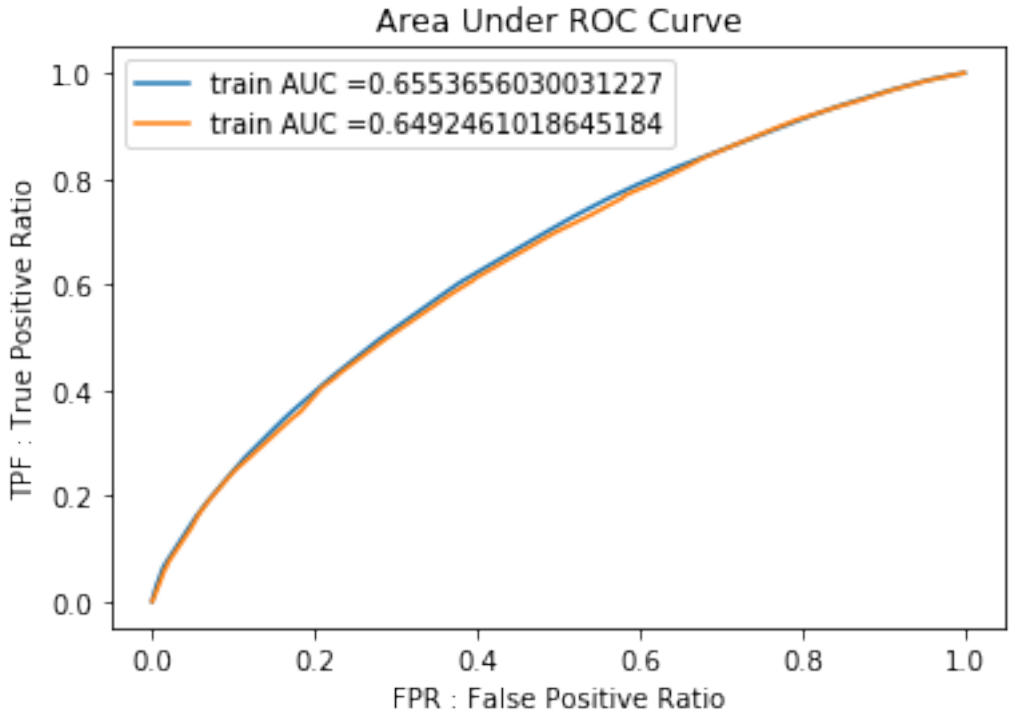
```
CV iteration : alpha=0.5, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.5, penalty=l1, train_score=0.5, test_score=0.5
C=0.5, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.5, penalty=l2, train_score=0.657921832644347, test_score=0.653803217996
CV iteration : alpha=0.5, penalty=l2, train_score=0.6417012629170412, test_score=0.63872462733
CV iteration : alpha=0.5, penalty=l2, train_score=0.6584207658045156, test_score=0.65683167349
C=0.5, penalty=l2, train_score=0.6526812871219679, test_score=0.6497865062739634
CV iteration : alpha=1, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=1, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=1, penalty=l1, train_score=0.5, test_score=0.5
C=1, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=1, penalty=l2, train_score=0.519712878854895, test_score=0.514659038797803
CV iteration : alpha=1, penalty=l2, train_score=0.5210109004683176, test_score=0.51104354475850
CV iteration : alpha=1, penalty=l2, train_score=0.5168669255144022, test_score=0.5185678662237
C=1, penalty=l2, train_score=0.5191969016125383, test_score=0.5147568165933641
CV iteration : alpha=5, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=5, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=5, penalty=l1, train_score=0.5, test_score=0.5
C=5, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=5, penalty=l2, train_score=0.5182512306795499, test_score=0.5121656528004
CV iteration : alpha=5, penalty=l2, train_score=0.5209283175827024, test_score=0.5113488668823
CV iteration : alpha=5, penalty=l2, train_score=0.5156927322789435, test_score=0.5168532787989
C=5, penalty=l2, train_score=0.5182907601803987, test_score=0.5134559328272239
CV iteration : alpha=10, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=10, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=10, penalty=l1, train_score=0.5, test_score=0.5
C=10, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=10, penalty=l2, train_score=0.5172224359865706, test_score=0.512291151842
CV iteration : alpha=10, penalty=l2, train_score=0.5197911819878008, test_score=0.509707779234
CV iteration : alpha=10, penalty=l2, train_score=0.5154487907562333, test_score=0.517813954528
C=10, penalty=l2, train_score=0.5174874695768682, test_score=0.5132709618685144
CV iteration : alpha=50, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=50, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=50, penalty=l1, train_score=0.5, test_score=0.5
C=50, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=50, penalty=l2, train_score=0.5162883302702037, test_score=0.512388018379
CV iteration : alpha=50, penalty=l2, train_score=0.5195521253364581, test_score=0.508780234450
CV iteration : alpha=50, penalty=l2, train_score=0.5150596708643226, test_score=0.517146377840
C=50, penalty=l2, train_score=0.5169667088236615, test_score=0.5127715435565999
CV iteration : alpha=100, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=100, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=100, penalty=l1, train_score=0.5, test_score=0.5
C=100, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=100, penalty=l2, train_score=0.5163666599031262, test_score=0.512518878288
CV iteration : alpha=100, penalty=l2, train_score=0.5196822757521873, test_score=0.509157438115
CV iteration : alpha=100, penalty=l2, train_score=0.5150813616206231, test_score=0.516803175870
C=100, penalty=l2, train_score=0.5170434324253123, test_score=0.5128264974246103
CV iteration : alpha=500, penalty=l1, train_score=0.5, test_score=0.5
```

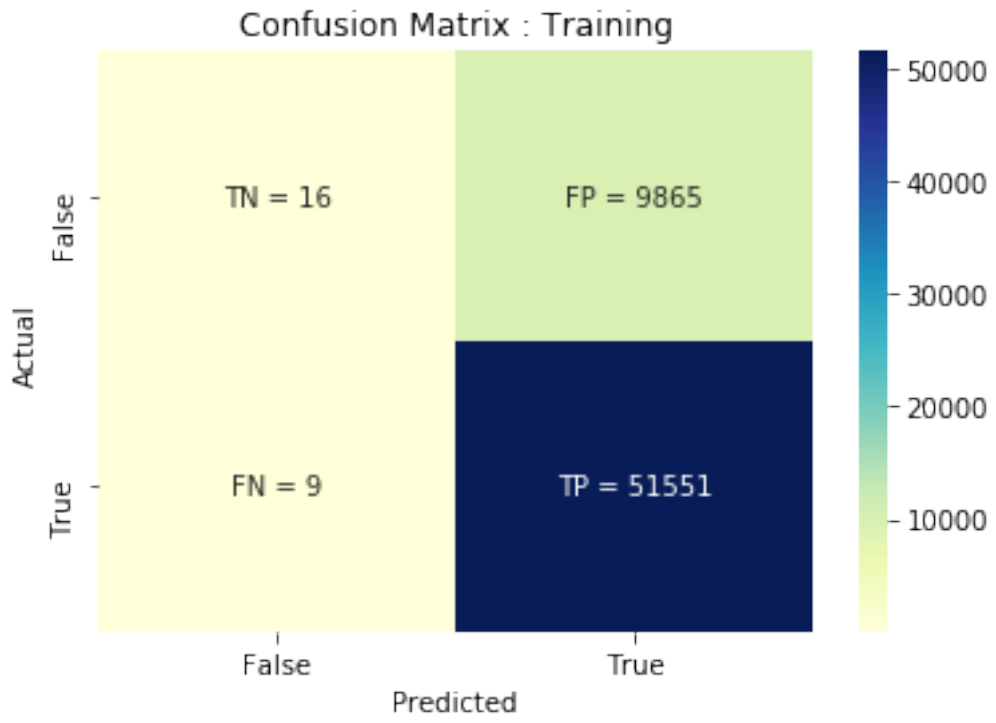
```
CV iteration : alpha=500, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=500, penalty=l1, train_score=0.5, test_score=0.5
C=500, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=500, penalty=l2, train_score=0.5163666599031262, test_score=0.512518878288
CV iteration : alpha=500, penalty=l2, train_score=0.5196822757521873, test_score=0.509157438115
CV iteration : alpha=500, penalty=l2, train_score=0.5150813616206231, test_score=0.516803175870
C=500, penalty=l2, train_score=0.5170434324253123, test_score=0.5128264974246103
CV iteration : alpha=1000, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=1000, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=1000, penalty=l1, train_score=0.5, test_score=0.5
C=1000, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=1000, penalty=l2, train_score=0.5163666599031262, test_score=0.512518878288
CV iteration : alpha=1000, penalty=l2, train_score=0.5196822757521873, test_score=0.509157438115
CV iteration : alpha=1000, penalty=l2, train_score=0.5150813616206231, test_score=0.516803175870
C=1000, penalty=l2, train_score=0.5170434324253123, test_score=0.5128264974246103
CV iteration : alpha=5000, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=5000, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=5000, penalty=l1, train_score=0.5, test_score=0.5
C=5000, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=5000, penalty=l2, train_score=0.5163666599031262, test_score=0.512518878288
CV iteration : alpha=5000, penalty=l2, train_score=0.5196822757521873, test_score=0.509157438115
CV iteration : alpha=5000, penalty=l2, train_score=0.5150813616206231, test_score=0.516803175870
C=5000, penalty=l2, train_score=0.5170434324253123, test_score=0.5128264974246103
CV iteration : alpha=10000, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=10000, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=10000, penalty=l1, train_score=0.5, test_score=0.5
C=10000, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=10000, penalty=l2, train_score=0.5163666599031262, test_score=0.512518878288
CV iteration : alpha=10000, penalty=l2, train_score=0.5196822757521873, test_score=0.509157438115
CV iteration : alpha=10000, penalty=l2, train_score=0.5150813616206231, test_score=0.516803175870
C=10000, penalty=l2, train_score=0.5170434324253123, test_score=0.5128264974246103
```

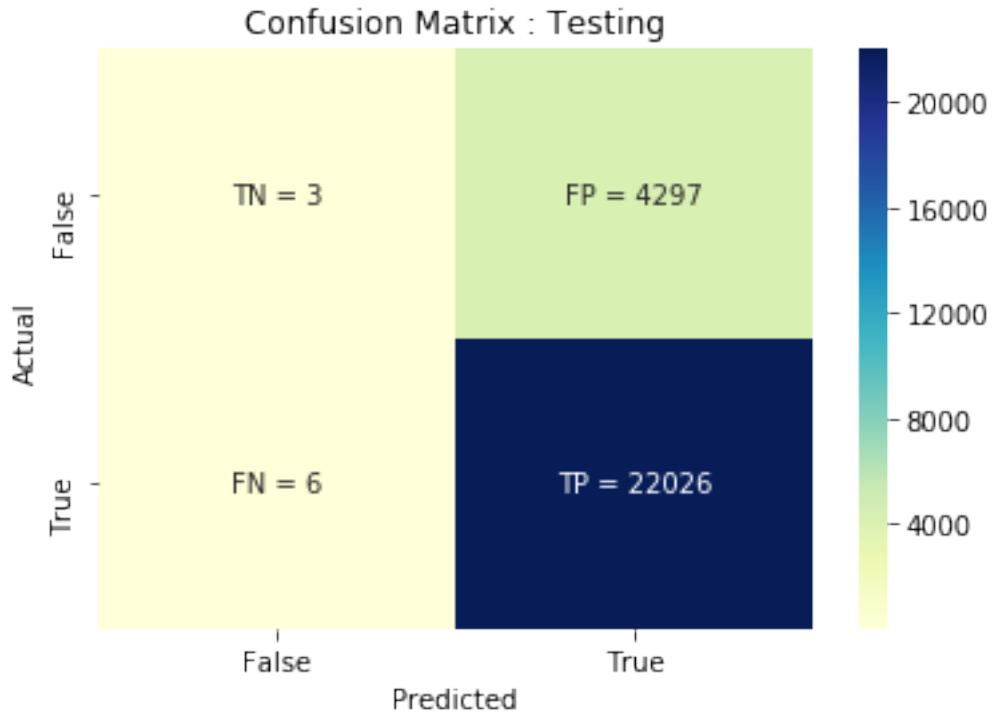


```
{'svm__alpha': 0.0001, 'svm__penalty': 'l2'}
Initializing Vectorizer
Training Model...
Saving Trained Model...
Retraining Vectorizer with Dx_train
Area Under the Curve for Train :  0.6553656030031227
Area Under the Curve for Test :  0.6492461018645184
```




Confusion Matrix : Training
TN = 16
FP = 9865
FN = 9
TP = 51551
False
True
Actual
False
True
Predicted
50000
40000
30000
20000
10000


Confusion Matrix : Testing
TN = 3
FP = 4297
FN = 6
TP = 22026
False
True
Actual
False
True
Predicted
20000
16000
12000
8000
4000

### 7.2.2 [5.1.4] Applying Linear SVM on TFIDF W2V, SET 4

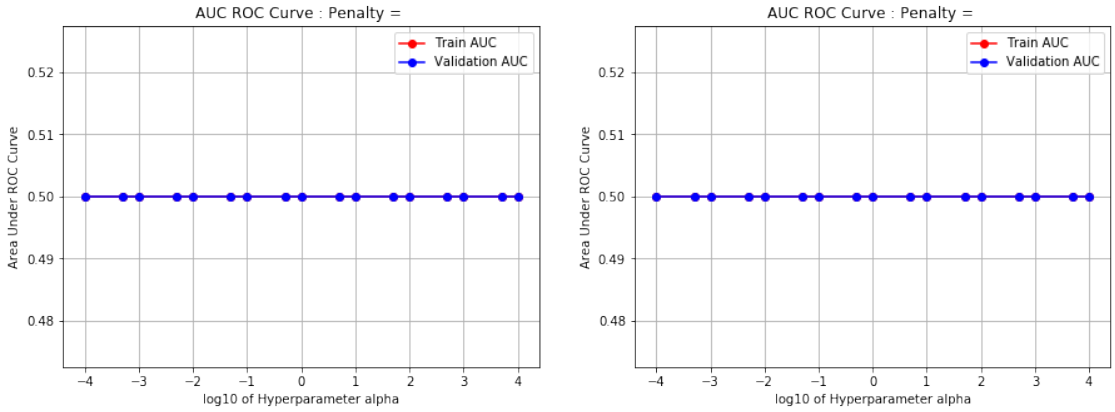
In [49]:
```
# Please write all the code with proper documentation
csv_path = 'saved_models/Assignment7/TFIDF-W2Vec_svm_results.csv'
cv_results = perform_hyperparameter_tuning(X=Dx_train, Y=Dy_train, vectorizer='TFIDF-W
                                           penalty=['l1', 'l2'], results_path=csv_path
                                           retrain=True, W2V_model=w2v_model)
# Analysing best parameters
best_parameters = analyse_results(cv_results)
pprint.pprint(best_parameters)
# retraining the model with best parameters
model_path = 'saved_models/Assignment7/{0}_svm.pkl'.format('TFIDF-W2Vec')
calibrated_svm = retrain_with_best_params(Dx_train, Dy_train, best_parameters, 'TFIDF-

print('Retraining Vectorizer with Dx_train')
vectorizer_obj = get_vectorizer(W2V_model = w2v_model, train=Dx_train, vectorizer='TFI

# plotting AUC ROC
train_score, test_score = plot_AUC_ROC(calibrated_svm, vectorizer_obj, Dx_train, Dx_te

# appending the data results
prettytable_data.append(['TFIDF-W2Vec', 'SVM', best_parameters['svm__penalty'], best_p
```

```
Performing Hyperparameter Tuning...

CV iteration : alpha=0.0001, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.0001, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.0001, penalty=l1, train_score=0.5, test_score=0.5
C=0.0001, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.0001, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.0001, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.0001, penalty=l2, train_score=0.5, test_score=0.5
C=0.0001, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.0005, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.0005, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.0005, penalty=l1, train_score=0.5, test_score=0.5
C=0.0005, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.0005, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.0005, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.0005, penalty=l2, train_score=0.5, test_score=0.5
C=0.0005, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.001, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.001, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.001, penalty=l1, train_score=0.5, test_score=0.5
C=0.001, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.001, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.001, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.001, penalty=l2, train_score=0.5, test_score=0.5
C=0.001, penalty=l2, train_score=0.5, test_score=0.5
```

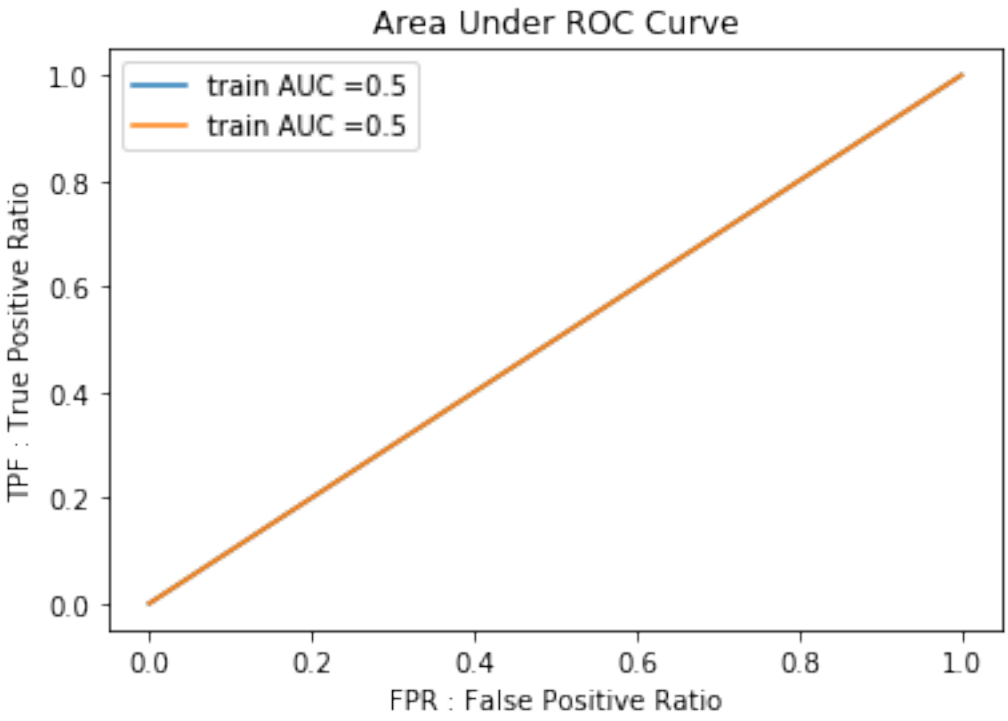
```
CV iteration : alpha=0.005, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.005, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.005, penalty=l1, train_score=0.5, test_score=0.5
C=0.005, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.005, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.005, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.005, penalty=l2, train_score=0.5, test_score=0.5
C=0.005, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.01, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.01, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.01, penalty=l1, train_score=0.5, test_score=0.5
C=0.01, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.01, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.01, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.01, penalty=l2, train_score=0.5, test_score=0.5
C=0.01, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.05, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.05, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.05, penalty=l1, train_score=0.5, test_score=0.5
C=0.05, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.05, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.05, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.05, penalty=l2, train_score=0.5, test_score=0.5
C=0.05, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.1, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.1, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.1, penalty=l1, train_score=0.5, test_score=0.5
C=0.1, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.1, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.1, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.1, penalty=l2, train_score=0.5, test_score=0.5
C=0.1, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.5, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.5, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.5, penalty=l1, train_score=0.5, test_score=0.5
C=0.5, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=0.5, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.5, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=0.5, penalty=l2, train_score=0.5, test_score=0.5
C=0.5, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=1, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=1, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=1, penalty=l1, train_score=0.5, test_score=0.5
C=1, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=1, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=1, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=1, penalty=l2, train_score=0.5, test_score=0.5
C=1, penalty=l2, train_score=0.5, test_score=0.5
```

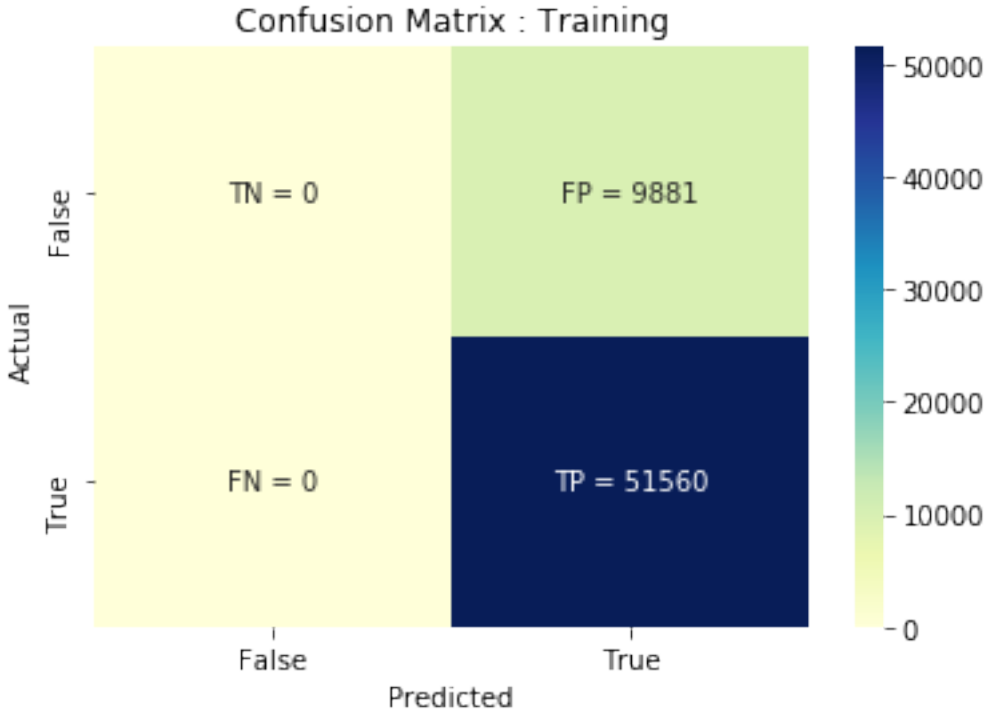
```
CV iteration : alpha=5, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=5, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=5, penalty=l1, train_score=0.5, test_score=0.5
C=5, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=5, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=5, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=5, penalty=l2, train_score=0.5, test_score=0.5
C=5, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=10, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=10, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=10, penalty=l1, train_score=0.5, test_score=0.5
C=10, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=10, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=10, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=10, penalty=l2, train_score=0.5, test_score=0.5
C=10, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=50, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=50, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=50, penalty=l1, train_score=0.5, test_score=0.5
C=50, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=50, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=50, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=50, penalty=l2, train_score=0.5, test_score=0.5
C=50, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=100, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=100, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=100, penalty=l1, train_score=0.5, test_score=0.5
C=100, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=100, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=100, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=100, penalty=l2, train_score=0.5, test_score=0.5
C=100, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=500, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=500, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=500, penalty=l1, train_score=0.5, test_score=0.5
C=500, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=500, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=500, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=500, penalty=l2, train_score=0.5, test_score=0.5
C=500, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=1000, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=1000, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=1000, penalty=l1, train_score=0.5, test_score=0.5
C=1000, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=1000, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=1000, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=1000, penalty=l2, train_score=0.5, test_score=0.5
C=1000, penalty=l2, train_score=0.5, test_score=0.5
```

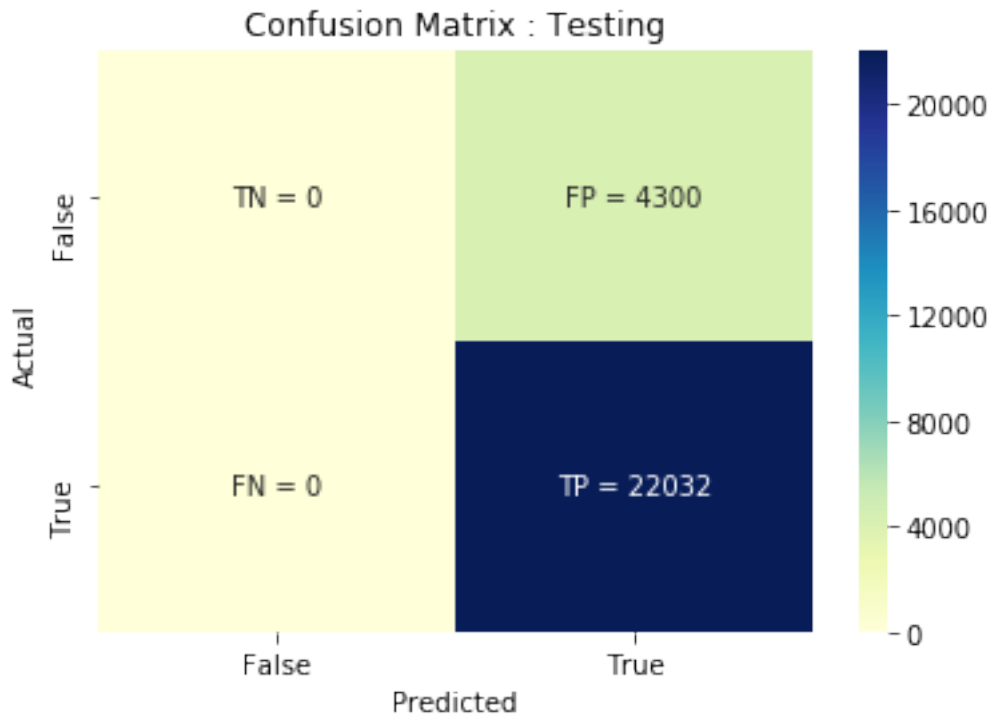
```
CV iteration : alpha=5000, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=5000, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=5000, penalty=l1, train_score=0.5, test_score=0.5
C=5000, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=5000, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=5000, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=5000, penalty=l2, train_score=0.5, test_score=0.5
C=5000, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=10000, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=10000, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=10000, penalty=l1, train_score=0.5, test_score=0.5
C=10000, penalty=l1, train_score=0.5, test_score=0.5
CV iteration : alpha=10000, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=10000, penalty=l2, train_score=0.5, test_score=0.5
CV iteration : alpha=10000, penalty=l2, train_score=0.5, test_score=0.5
C=10000, penalty=l2, train_score=0.5, test_score=0.5
```




```
{'svm__alpha': 0.0001, 'svm__penalty': 'l1'}
Initializing Vectorizer
Training Model...
Saving Trained Model...
Retraining Vectorizer with Dx_train
Area Under the Curve for Train :  0.5
Area Under the Curve for Test :  0.5
```


Area Under ROC Curve
train AUC =0.5
train AUC =0.5
TPF : True Positive Ratio
FPR : False Positive Ratio
0.0
0.2
0.4
0.6
0.8
1.0


Confusion Matrix : Training
TN = 0
FP = 9881
FN = 0
TP = 51560
Actual
False
True
Predicted
False
True
50000
40000
30000
20000
10000
0




### 7.3 [5.2] RBF SVM

```
In [50]: num_data_points = 40000
```

```
In [51]: Dx_train, Dx_test, Dy_train, Dy_test = train_test_split(preprocessed_reviews[:num_data
```

### 7.4 A great article that helped me a lot in understanding the parameters of SVC in depth

https://medium.com/all-things-ai/in-depth-parameter-tuning-for-svc-758215394769

```
In [52]: ## '''Perform Simple Cross Validation'''
         def perform_hyperparameter_tuning_rbf(X, Y, vectorizer, results_path, retrain=False, V
             #If the pandas dataframe with the hyperparameter info exists then return it

             if(retrain==False):
                 # If Cross Validation results exists then return them
                 if(os.path.exists(results_path)):
                     return pd.read_csv(results_path)
                 else:
                     # If no data exists but retrain=False then mention accordingly
                     print('Retrain is set to be False but no Cross Validation Results DataFra
             else:
                 # else perform hyperparameter tuning
```

```
print('Performing Hyperparameter Tuning...\n')
# regularization parameter
hyperparameters = {
    'svm__C' : [0.0001, 0.01, 1, 100, 10000],
}

C_values = []

train_scores = []
test_scores = []

train_mean_score = []
test_mean_score = []

# Initializing KFold
skf = StratifiedKFold(n_splits=3)
X = np.array(X)
Y = np.array(Y)

for C in hyperparameters['svm__C']:

    #Performing Cross Validation
    for train_index, test_index in skf.split(X, Y):
        Dx_train, Dx_cv = X[train_index], X[test_index]
        Dy_train, Dy_cv = Y[train_index], Y[test_index]

        #Initializing the Vectorizer
        vectorizer = get_vectorizer(vectorizer, Dx_train.tolist(), W2V_model)

        #Transforming the data to features
        x_train = vectorizer.transform(Dx_train.tolist())
        x_cv = vectorizer.transform(Dx_cv.tolist())

        #Initializing the LR model
        calib_svm = SVC(kernel='rbf', C=C, max_iter=1000, verbose=False, proba

        # Fit the model
        calib_svm.fit(x_train, Dy_train)

        #Prediction
        train_results = calib_svm.predict_proba(x_train)
        cv_results = calib_svm.predict_proba(x_cv)

        try:
            train_score = roc_auc_score(Dy_train, train_results[:, 1])
            test_score = roc_auc_score(Dy_cv, cv_results[:, 1])

            #storing the results to form a dataframe
```

```
                        train_scores.append(train_score)
                        test_scores.append(test_score)

                    except Exception as e:
                        print('Error Case : ', e)
                        print(('Actual, Predicted'))
                        [print((Dy_cv[i], cv_results[i, 1])) for i in range(len(Dy_cv))]


                train_mean_score.append(sum(train_scores)/len(train_scores))
                test_mean_score.append(sum(test_scores)/len(test_scores))

                C_values.append(C)

                print('C={0}, train_score={1}, test_score={2}'
                      .format(C, sum(train_scores)/len(train_scores), sum(test_scores)/le

                train_scores = []
                test_scores = []

            # Creating a DataFrame from the saved data for visualization
            results_df = pd.DataFrame({'C' : C_values, 'train_score' : train_mean_score,
                                       'test_score': test_mean_score})

            #writing the results to csv after performing hyperparameter tuning
            try:
                results_df.to_csv(results_path)
            except Exception as ex:
                print(str(ex), "\nError occured while converting DataFrame to CSV after c
            return results_df
```

In [53]:
```
def analyse_results(df):
    # plotting error curves
    fig = plt.figure()
    ax = fig.gca()

    plt.plot([math.log10(i) for i in df.C.tolist()], df.test_score.tolist(), '-o', c=
    plt.plot([math.log10(i) for i in df.C.tolist()], df.train_score.tolist(), '-o', c=
    plt.grid(True)
    plt.xlabel('log10 of "C"')
    plt.ylabel('Area Under ROC Curve')
    plt.title('AUC ROC Curve for Logistic Regression')
    plt.legend(loc='best')
    plt.show()

    # return the best parameters
    mmax = 0
    ind_max = 0
```

```
            for index, row in df.iterrows():
                if(row['test_score']>mmax):
                    mmax=row['test_score']
                    ind_max = index


            best_params = {
                'svm__C': df.loc[ind_max, 'C']
            }

            return best_params
```

```
In [54]: def retrain_with_best_params(data, labels, best_params, vec_name, model_path, word2ve
            if(os.path.exists(model_path)):
                print('Loading Model....')
                with open(model_path, 'rb') as input_file:
                    calib_svm = pickle.load(input_file)
            else:
                calib_svm = SVC(kernel='rbf', C=best_params['svm__C'], max_iter=1000, verbose=

                print('Initializing Vectorizer')
                vectorizer = get_vectorizer(vectorizer=vec_name, train=data, W2V_model=word2ve
                print('Training Model....')
                calib_svm.fit(vectorizer.transform(data), np.array(labels))

                print('Saving Trained Model....')
                with open(model_path,'wb') as file:
                    pickle.dump(calib_svm, file)
            return calib_svm
```

```
In [55]: def plot_confusion_matrix(model, data, labels, dataset_label):
            pred = model.predict(data)
            conf_mat = confusion_matrix(labels, pred)

            strings = strings = np.asarray([['TN = ', 'FP = '],
                                            ['FN = ', 'TP = ']])

            labels = (np.asarray(["{0}{1}".format(string, value)
                                  for string, value in zip(strings.flatten(),
                                                           conf_mat.flatten())])
                      ).reshape(2, 2)

            fig, ax = plt.subplots()
            ax.set(xlabel='Predicted', ylabel='Actual', title='Confusion Matrix : {0}'.format
            sns.heatmap(conf_mat, annot=labels, fmt="", cmap='YlGnBu', ax=ax)
            ax.set_xlabel('Predicted')
            ax.set_ylabel('Actual')
            ax.set_xticklabels(['False', 'True'])
```

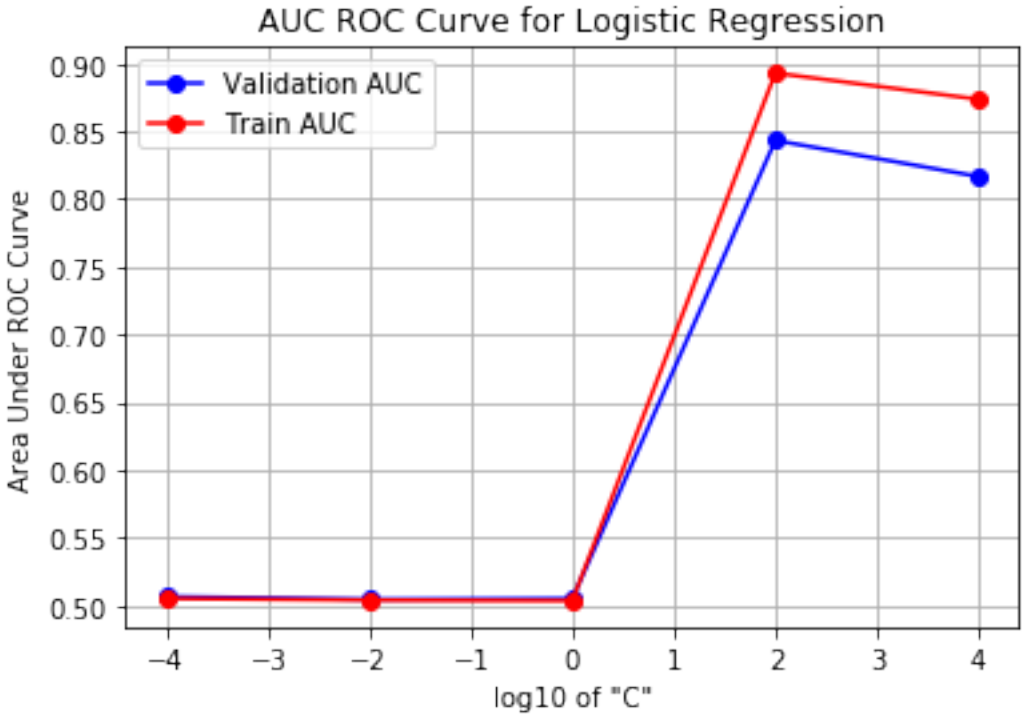
```
    ax.set_yticklabels(['False', 'True'])
    plt.show()
```

```
In [56]: def plot_AUC_ROC(model, vectorizer, Dx_train, Dx_test, Dy_train, Dy_test):

    #predicting probability of Dx_test, Dx_train
    test_score = model.predict_proba(vectorizer.transform(Dx_test))
    train_score = model.predict_proba(vectorizer.transform(Dx_train))

    #Finding out the ROC_AUC_SCORE
    train_roc_auc_score = roc_auc_score(np.array(Dy_train), train_score[:, 1])
    print('Area Under the Curve for Train : ', train_roc_auc_score)
    test_roc_auc_score = roc_auc_score(np.array(Dy_test), test_score[:, 1])
    print('Area Under the Curve for Test : ', test_roc_auc_score)

    #Plotting with matplotlib.pyplot
    #ROC Curve for D-train
    train_fpr, train_tpr, thresholds = roc_curve(np.array(Dy_train), train_score[:, 1
    plt.plot(train_fpr, train_tpr, label="train AUC ="+str(auc(train_fpr, train_tpr))

    # #ROC Curve for D-test
    test_fpr, test_tpr, thresholds = roc_curve(np.array(Dy_test), test_score[:, 1])
    plt.plot(test_fpr, test_tpr, label="train AUC ="+str(auc(test_fpr, test_tpr)))

    plt.legend()
    plt.xlabel("FPR : False Positive Ratio")
    plt.ylabel("TPF : True Positive Ratio")
    plt.title("Area Under ROC Curve")
    plt.show()

    plot_confusion_matrix(model, vectorizer.transform(Dx_train), np.array(Dy_train),
    plot_confusion_matrix(model, vectorizer.transform(Dx_test), np.array(Dy_test), 'Te
    return train_roc_auc_score, test_roc_auc_score
```

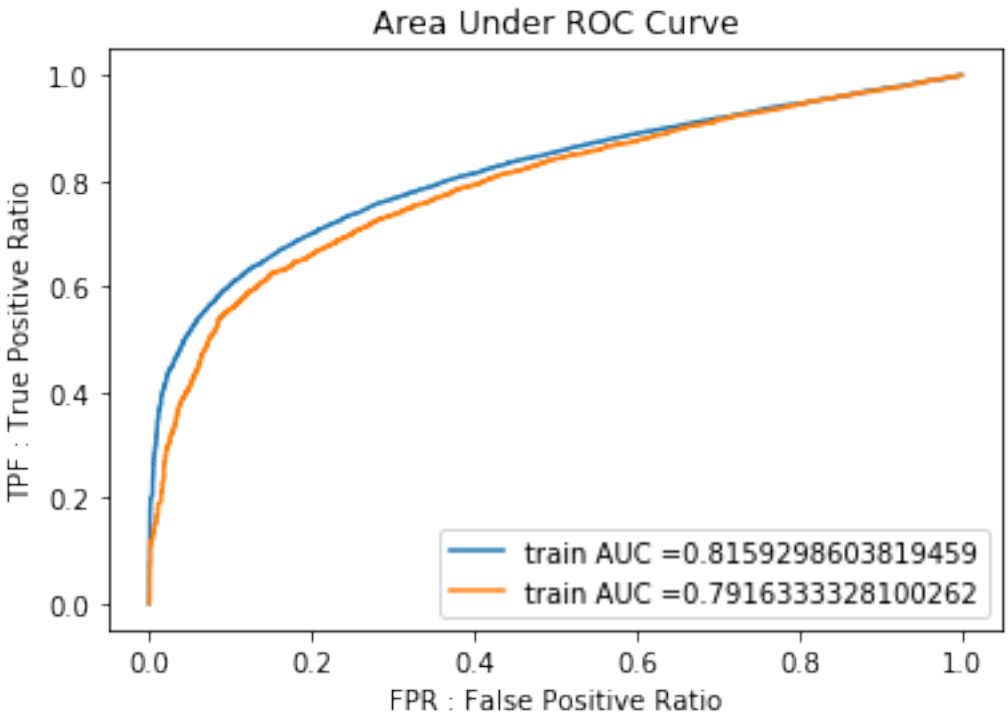
### 7.4.1 [5.2.1] Applying RBF SVM on BOW, SET 1

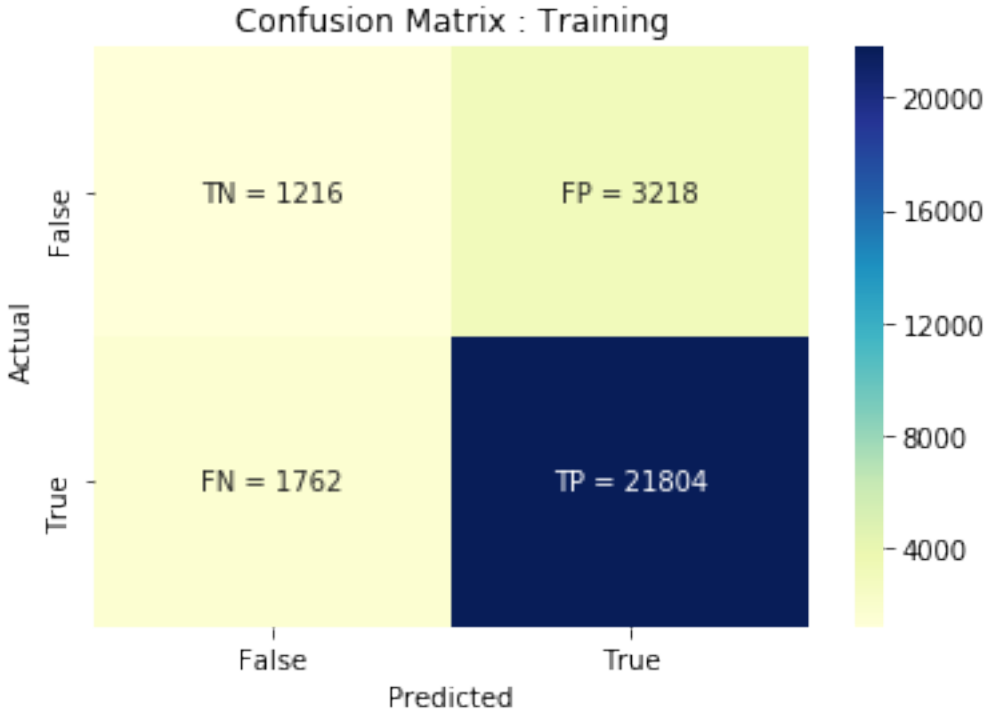
```
In [57]: # Please write all the code with proper documentation
         csv_path = 'saved_models/Assignment7/BOW_svm_rbf_results.csv'
         cv_results = perform_hyperparameter_tuning_rbf(X=Dx_train, Y=Dy_train, vectorizer='BOW
                                                        results_path=csv_path, retrain=False, W2V_r
         # Analysing best parameters
         best_parameters = analyse_results(cv_results)
         pprint.pprint(best_parameters)
         # retraining the model with best parameters
         model_path = 'saved_models/Assignment7/{0}_svm_rbf.pkl'.format('BOW')
         calibrated_svm = retrain_with_best_params(Dx_train, Dy_train, best_parameters, 'BOW',

         print('Retraining Vectorizer with Dx_train')
```

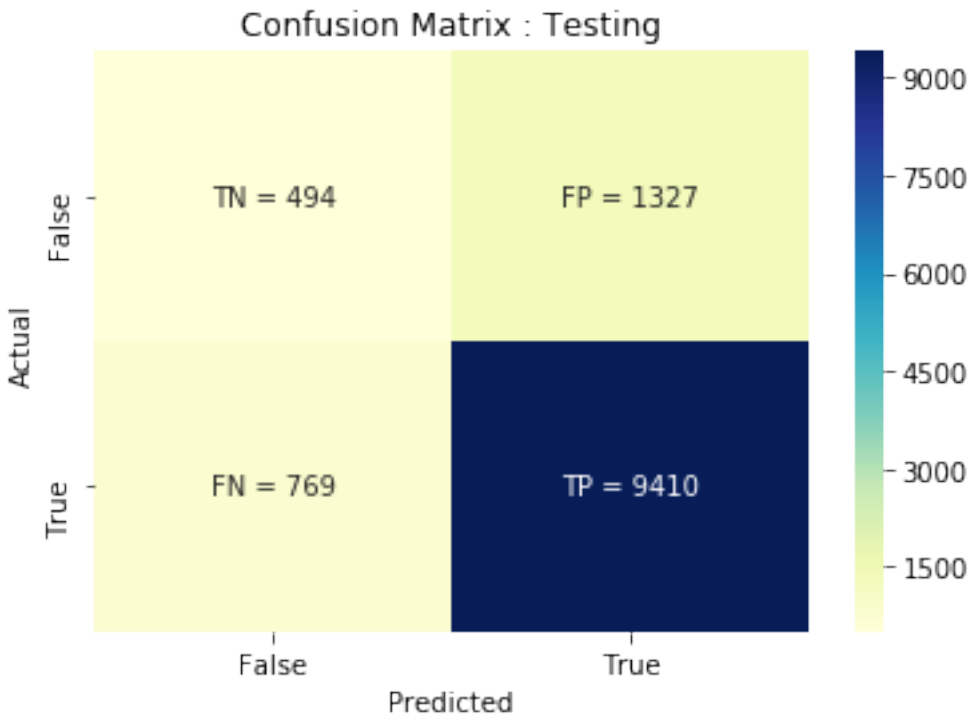
```
vectorizer_obj = get_vectorizer(W2V_model = None, train=Dx_train, vectorizer='BOW')

# plotting AUC ROC
train_score, test_score = plot_AUC_ROC(calibrated_svm, vectorizer_obj, Dx_train, Dx_te

# appending the data results
prettytable_data.append(['BOW', 'SVM-rbf', best_parameters['svm__C'], None, train_scor
```




```
{'svm__C': 100.0}
Loading Model...
Retraining Vectorizer with Dx_train
Area Under the Curve for Train :  0.8159298603819459
Area Under the Curve for Test :  0.7916333328100262
```

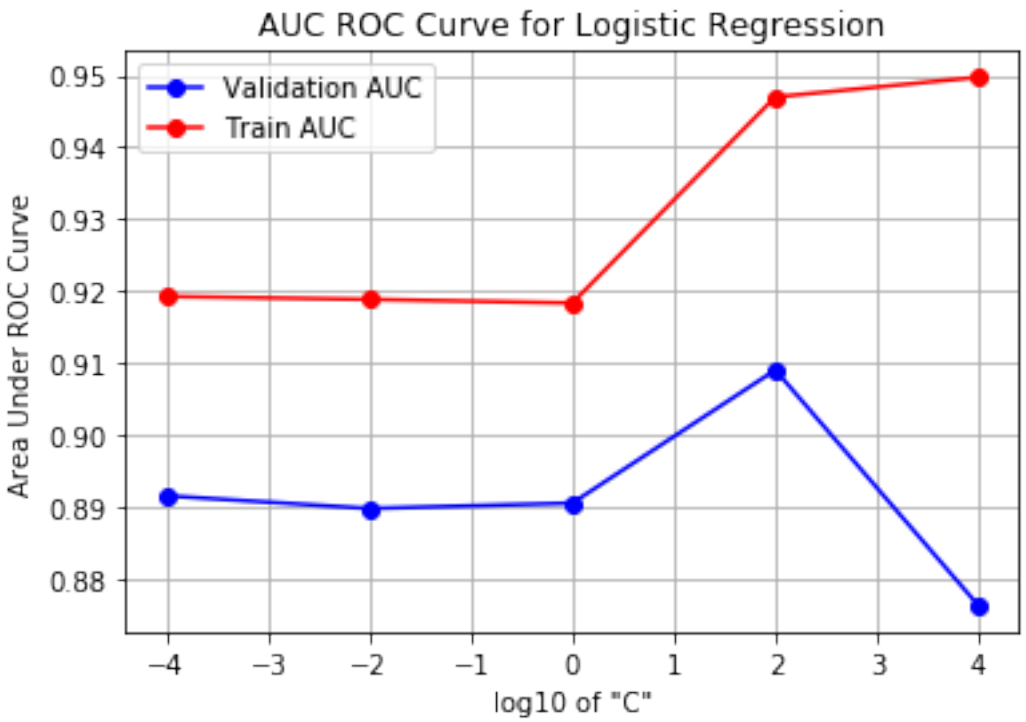

Area Under ROC Curve
TPF : True Positive Ratio
FPR : False Positive Ratio
train AUC =0.8159298603819459
train AUC =0.7916333328100262
0.0
0.2
0.4
0.6
0.8
1.0


Confusion Matrix : Training
TN = 1216
FP = 3218
FN = 1762
TP = 21804
Actual
False
True
Predicted
False
True
20000
16000
12000
8000
4000

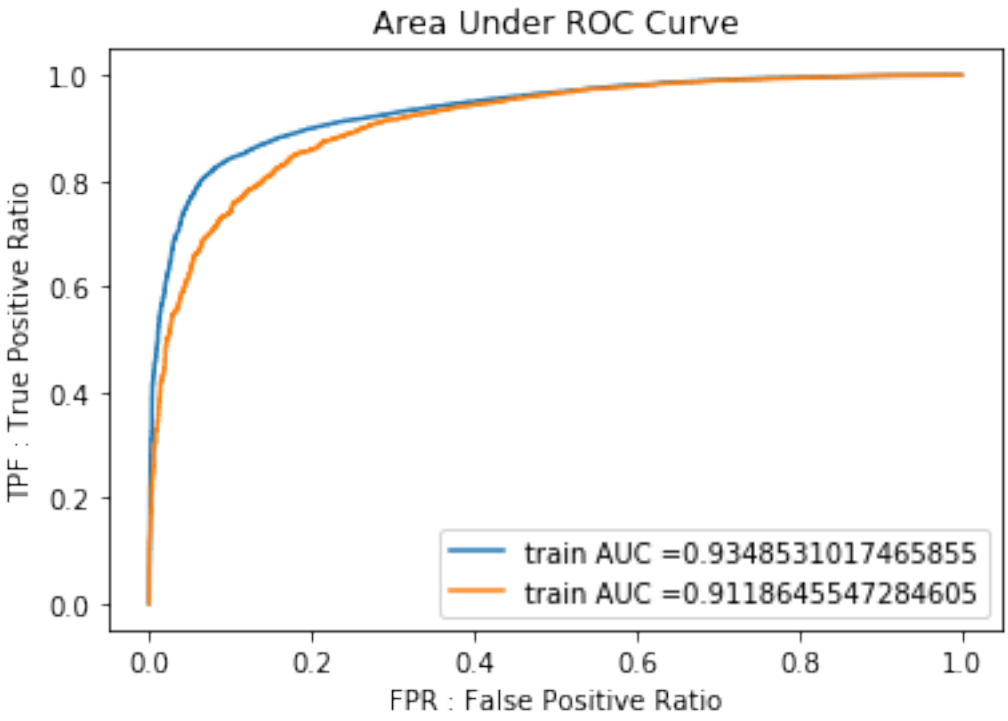


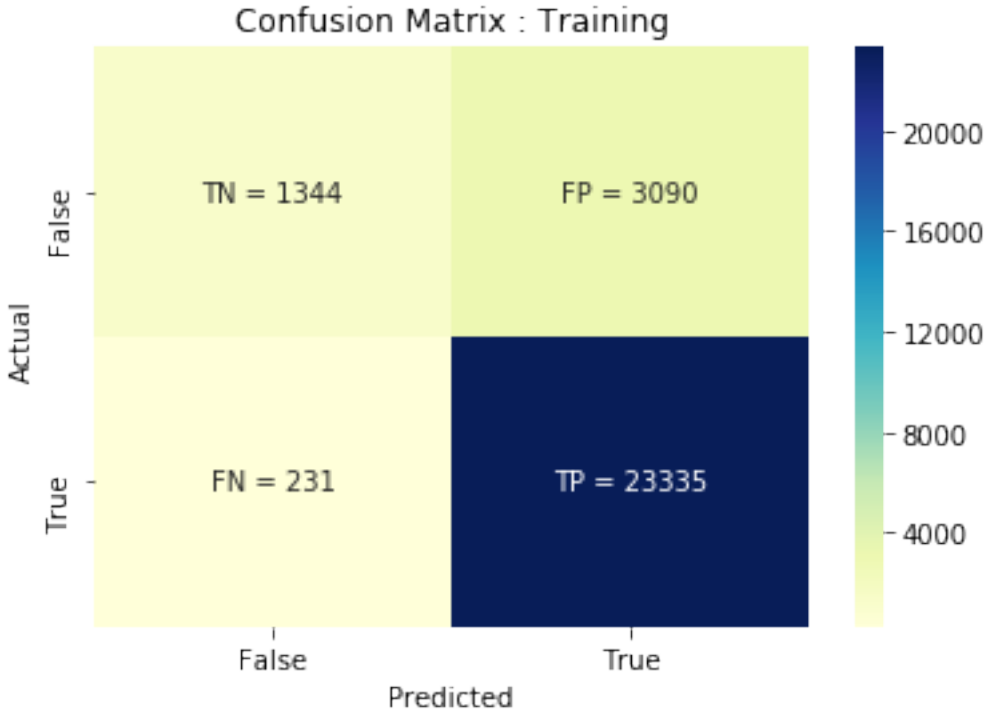

### 7.4.2 [5.2.2] Applying RBF SVM on TFIDF, SET 2

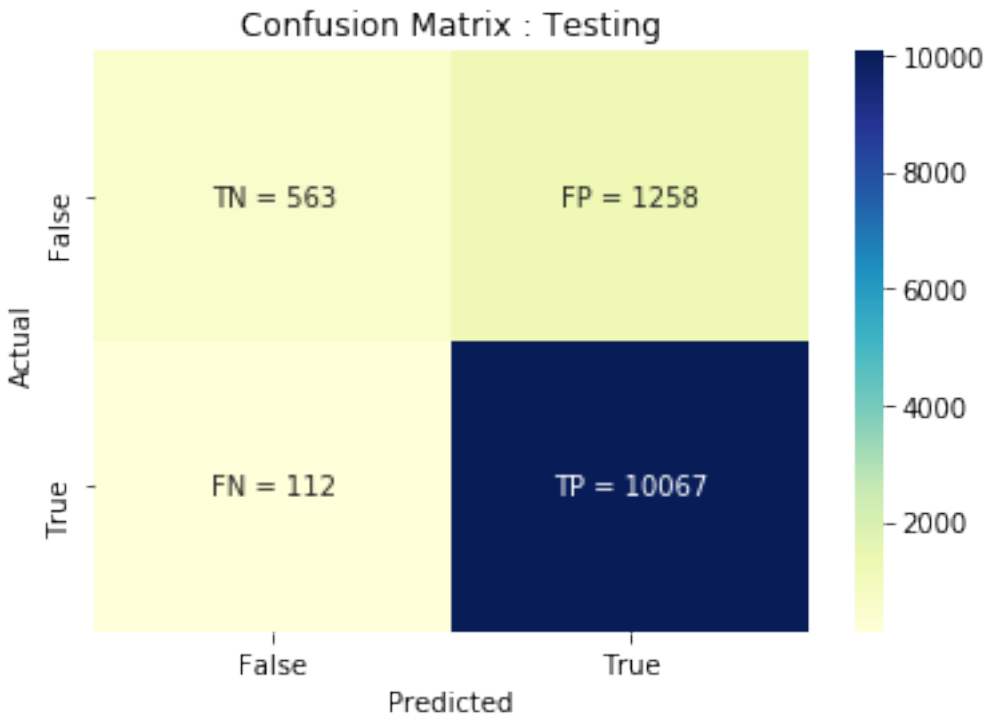
```
In [58]: # Please write all the code with proper documentation
         csv_path = 'saved_models/Assignment7/TFIDF_svm_rbf_results.csv'
         cv_results = perform_hyperparameter_tuning_rbf(X=Dx_train, Y=Dy_train, vectorizer='TF
                                                        results_path=csv_path, retrain=False, W2V_
         # Analysing best parameters
         best_parameters = analyse_results(cv_results)
         pprint.pprint(best_parameters)
         # retraining the model with best parameters
         model_path = 'saved_models/Assignment7/{0}_svm_rbf.pkl'.format('TFIDF')
         calibrated_svm = retrain_with_best_params(Dx_train, Dy_train, best_parameters, 'TFIDF

         print('Retraining Vectorizer with Dx_train')
         vectorizer_obj = get_vectorizer(W2V_model = None, train=Dx_train, vectorizer='TFIDF')

         # plotting AUC ROC
         train_score, test_score = plot_AUC_ROC(calibrated_svm, vectorizer_obj, Dx_train, Dx_te

         # appending the data results
         prettytable_data.append(['TFIDF', 'SVM-rbf', best_parameters['svm__C'], None, train_sc
```




```
{'svm__C': 100.0}
Loading Model...
Retraining Vectorizer with Dx_train
Area Under the Curve for Train :  0.9348531017465855
Area Under the Curve for Test :  0.9118645547284605
```


Area Under ROC Curve
TPF : True Positive Ratio
FPR : False Positive Ratio
train AUC =0.9348531017465855
train AUC =0.9118645547284605
0.0
0.2
0.4
0.6
0.8
1.0

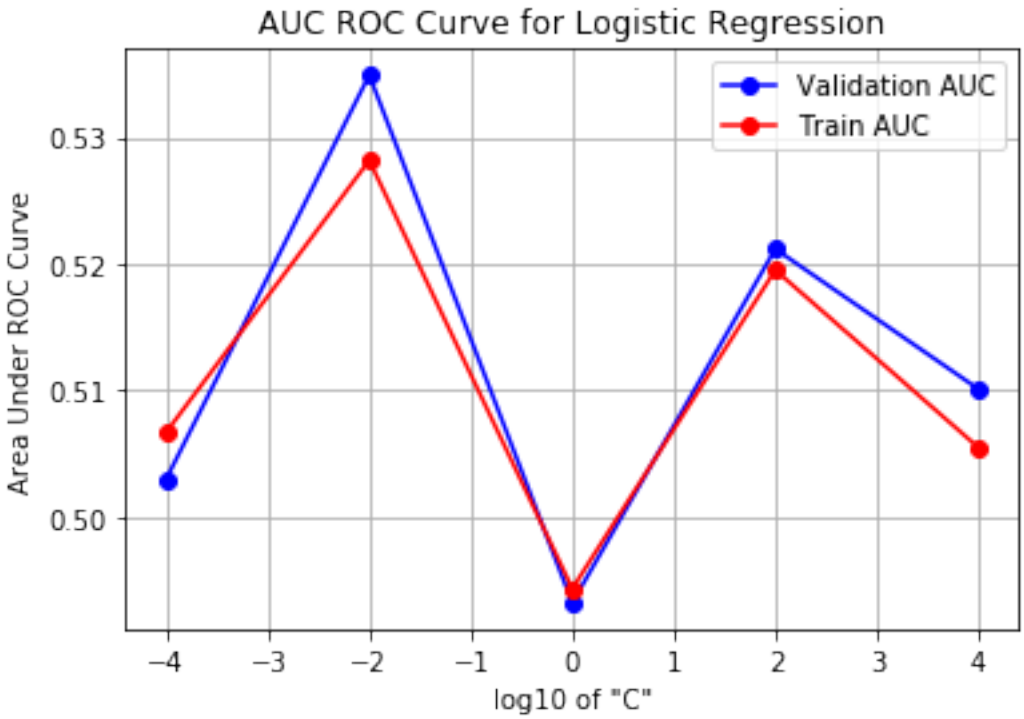

Confusion Matrix : Training
TN = 1344
FP = 3090
FN = 231
TP = 23335
Actual
False
True
Predicted
False
True
20000
16000
12000
8000
4000



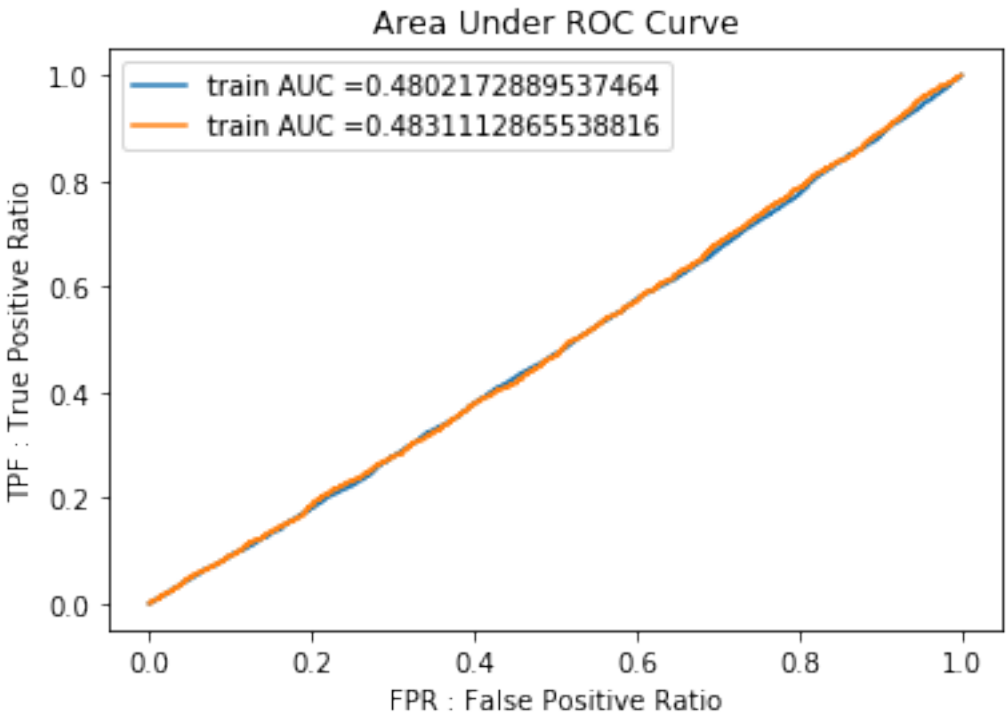

### 7.4.3 [5.2.3] Applying RBF SVM on AVG W2V, SET 3

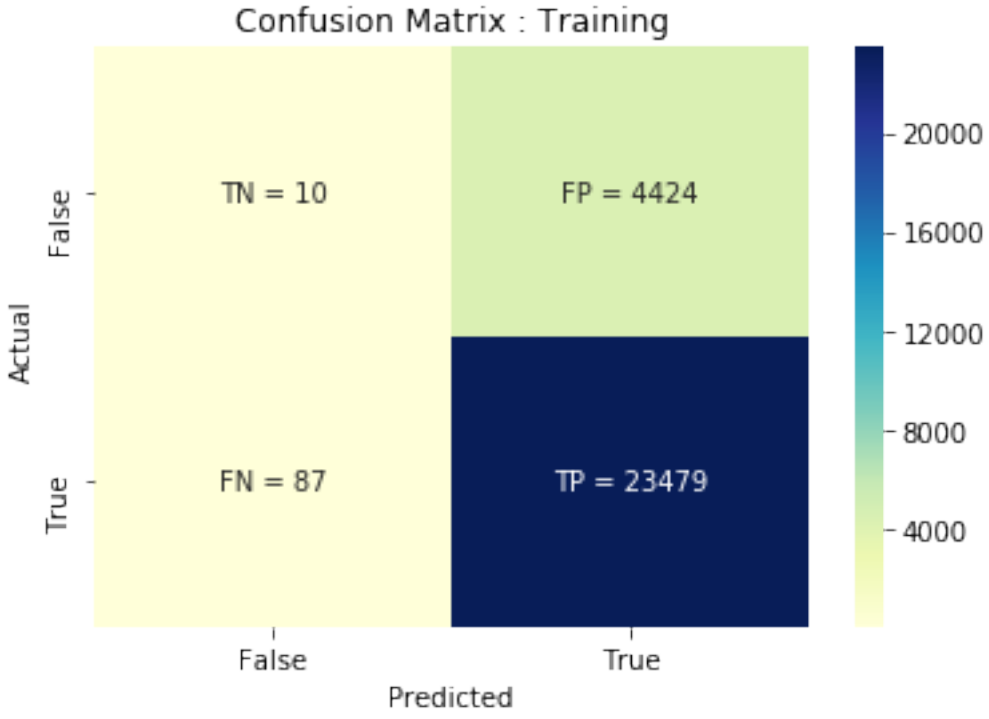
```
In [59]: # Please write all the code with proper documentation
         csv_path = 'saved_models/Assignment7/Avg-W2Vec_svm_rbf_results.csv'
         cv_results = perform_hyperparameter_tuning_rbf(X=Dx_train, Y=Dy_train, vectorizer='Avg
                                                        results_path=csv_path, retrain=True, W2V_mo
         # Analysing best parameters
         best_parameters = analyse_results(cv_results)
         pprint.pprint(best_parameters)
         # retraining the model with best parameters
         model_path = 'saved_models/Assignment7/{0}_svm_rbf.pkl'.format('Avg-W2Vec')
         calibrated_svm = retrain_with_best_params(Dx_train, Dy_train, best_parameters, 'Avg-W2

         print('Retraining Vectorizer with Dx_train')
         vectorizer_obj = get_vectorizer(W2V_model = w2v_model, train=Dx_train, vectorizer='Avg

         # plotting AUC ROC
         train_score, test_score = plot_AUC_ROC(calibrated_svm, vectorizer_obj, Dx_train, Dx_te

         # appending the data results
         prettytable_data.append(['Avg-W2Vec', 'SVM-rbf', best_parameters['svm__C'], None, trai

Performing Hyperparameter Tuning...
```

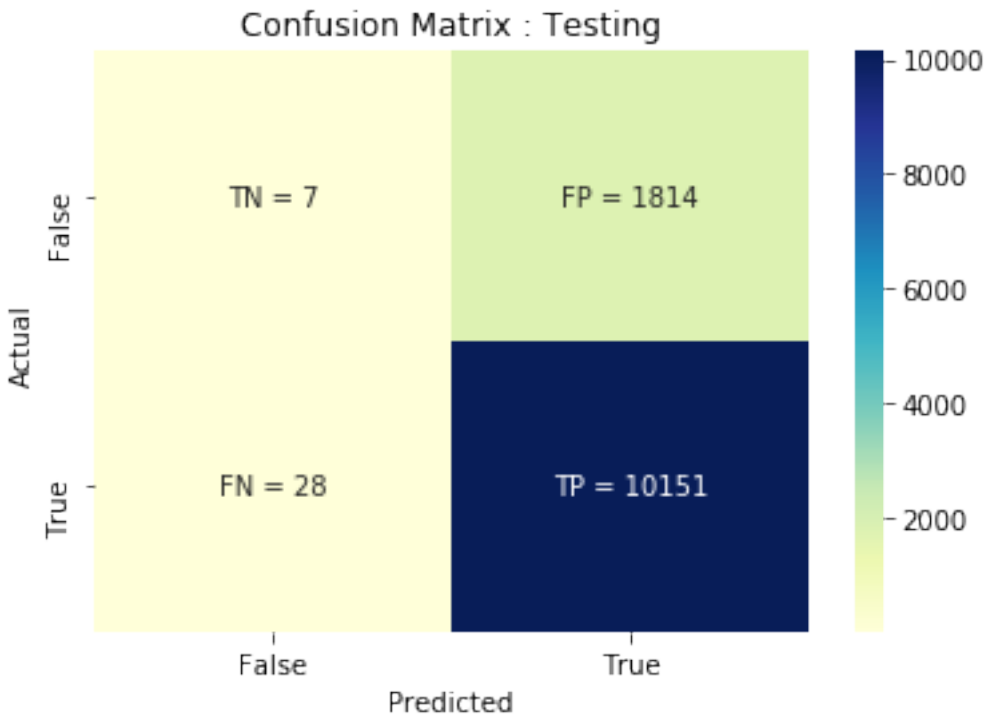
```
C=0.0001, train_score=0.5066795583911804, test_score=0.5029801141328885
C=0.01, train_score=0.528162579761382, test_score=0.5349074065240971
C=1, train_score=0.49431304584432945, test_score=0.49320339706620997
C=100, train_score=0.5194949951403993, test_score=0.5211663363414948
C=10000, train_score=0.5054711810816822, test_score=0.5100912423750392
```




```
{'svm__C': 0.01}
Initializing Vectorizer
Training Model...
Saving Trained Model...
Retraining Vectorizer with Dx_train
Area Under the Curve for Train :  0.4802172889537464
Area Under the Curve for Test :  0.4831112865538816
```


Area Under ROC Curve
train AUC =0.4802172889537464
train AUC =0.4831112865538816
TPF : True Positive Ratio
FPR : False Positive Ratio
0.0
0.2
0.4
0.6
0.8
1.0

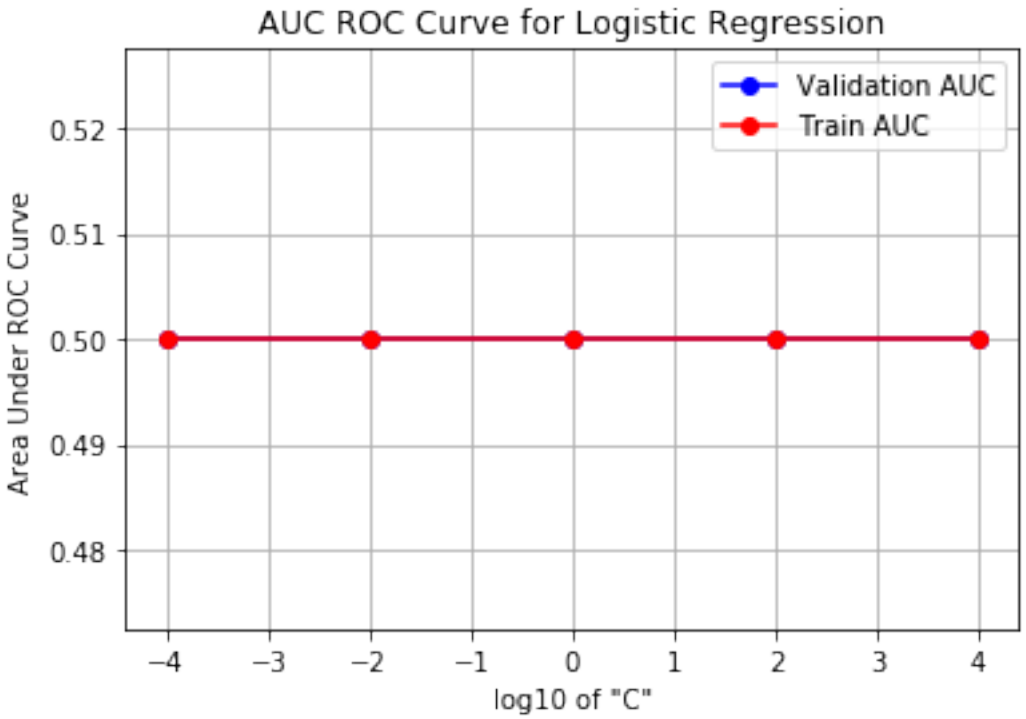

Confusion Matrix : Training
TN = 10
FP = 4424
FN = 87
TP = 23479
Actual
False
True
Predicted
20000
16000
12000
8000
4000



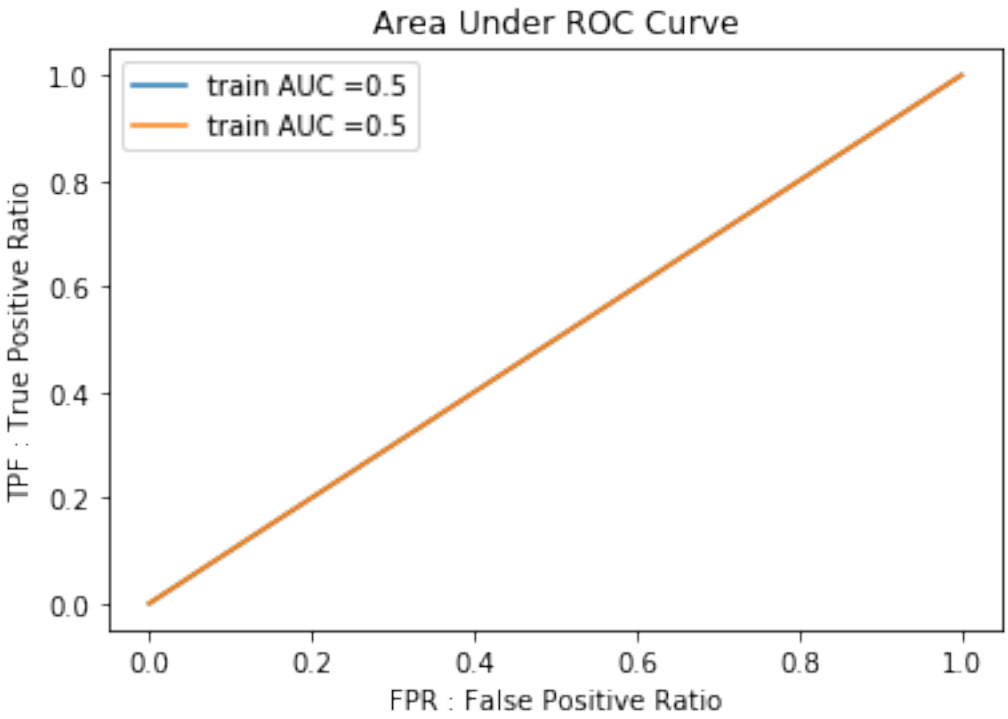

### 7.4.4 [5.2.4] Applying RBF SVM on TFIDF W2V, SET 4

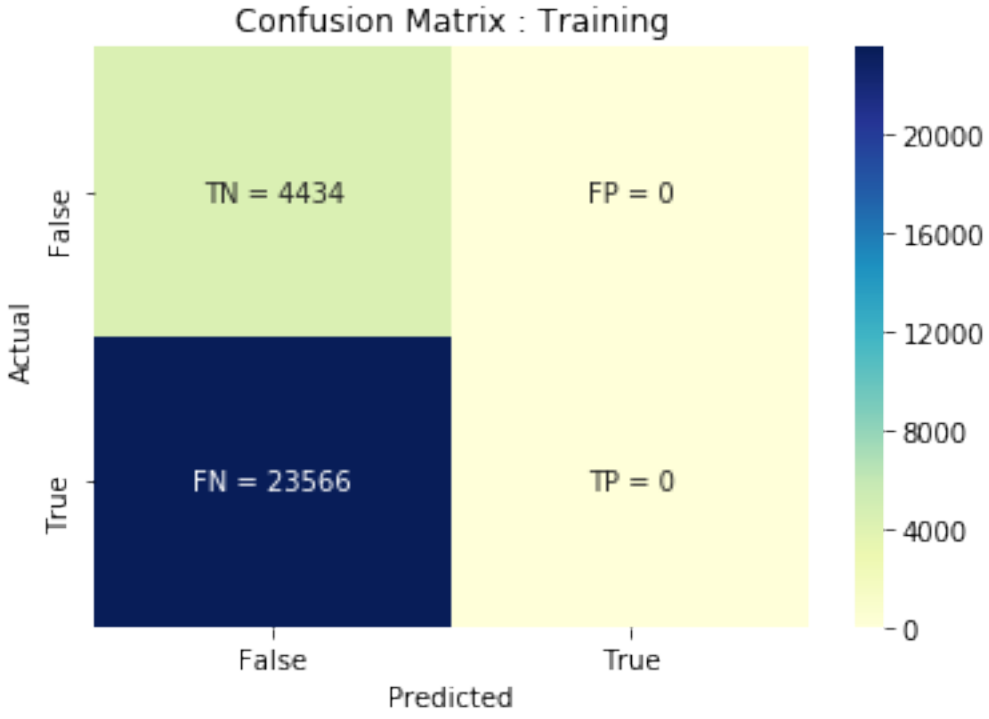
```
In [60]: # Please write all the code with proper documentation
         csv_path = 'saved_models/Assignment7/TFIDF-W2Vec_svm_rbf_results.csv'
         cv_results = perform_hyperparameter_tuning_rbf(X=Dx_train, Y=Dy_train, vectorizer='TF
                                                        results_path=csv_path, retrain=True, W2V_m
         # Analysing best parameters
         best_parameters = analyse_results(cv_results)
         pprint.pprint(best_parameters)
         # retraining the model with best parameters
         model_path = 'saved_models/Assignment7/{0}_svm_rbf.pkl'.format('TFIDF-W2Vec')
         calibrated_svm = retrain_with_best_params(Dx_train, Dy_train, best_parameters, 'TFIDF

         print('Retraining Vectorizer with Dx_train')
         vectorizer_obj = get_vectorizer(W2V_model = w2v_model, train=Dx_train, vectorizer='TF

         # plotting AUC ROC
         train_score, test_score = plot_AUC_ROC(calibrated_svm, vectorizer_obj, Dx_train, Dx_te

         # appending the data results
         prettytable_data.append(['TFIDF-W2Vec', 'SVM-rbf', best_parameters['svm__C'], None, tr

Performing Hyperparameter Tuning...
```

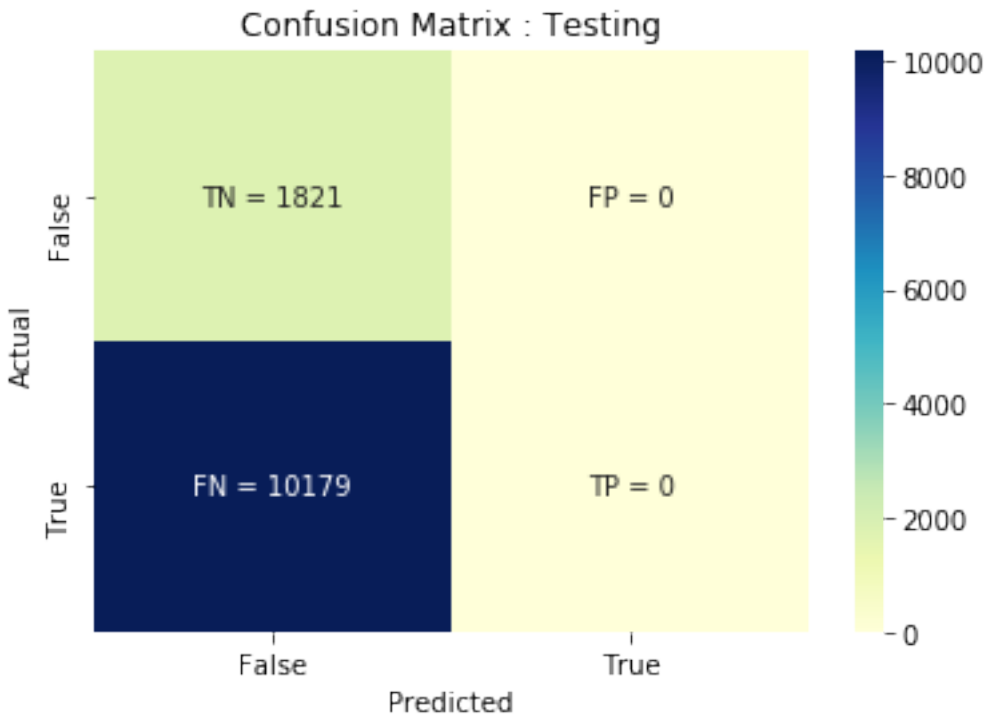
```
C=0.0001, train_score=0.5, test_score=0.5
C=0.01, train_score=0.5, test_score=0.5
C=1, train_score=0.5, test_score=0.5
C=100, train_score=0.5, test_score=0.5
C=10000, train_score=0.5, test_score=0.5
```




```
{'svm__C': 0.0001}
Initializing Vectorizer
Training Model...
Saving Trained Model...
Retraining Vectorizer with Dx_train
Area Under the Curve for Train :  0.5
Area Under the Curve for Test :  0.5
```


Area Under ROC Curve
train AUC =0.5
train AUC =0.5
TPF : True Positive Ratio
FPR : False Positive Ratio
0.0
0.2
0.4
0.6
0.8
1.0


Confusion Matrix : Training
TN = 4434
FP = 0
FN = 23566
TP = 0
Actual
False
True
Predicted
False
True
20000
16000
12000
8000
4000
0




## 8 [6] Conclusions

```
In [61]: from prettytable import PrettyTable

In [62]: # Please compare all your models using Prettytable library
         x = PrettyTable()

         x.field_names = ["Vectorizer", "Model", "Penalty", "Hyper parameter: 1/C", "Train AUC"
         [x.add_row(i) for i in prettytable_data]
         print(x)
```

```
+-------------+---------+---------+----------------------+--------------------+---------------
|  Vectorizer |  Model  | Penalty | Hyper parameter: 1/C |     Train AUC      |      Test AUC
+-------------+---------+---------+----------------------+--------------------+---------------
|     BOW     |   SVM   |    l2   |        0.001         | 0.967227654550752  |  0.94921858375
|    TFIDF    |   SVM   |    l2   |        0.0001        | 0.9661167505416866 | 0.958487601543
|  Avg-W2Vec  |   SVM   |    l2   |        0.0001        | 0.6553656030031227 | 0.649246101864
| TFIDF-W2Vec |   SVM   |    l1   |        0.0001        |        0.5         |        0.5
|     BOW     | SVM-rbf |  100.0  |         None         | 0.8159298603819459 | 0.791633332810
|    TFIDF    | SVM-rbf |  100.0  |         None         | 0.9348531017465855 | 0.911864554728
|  Avg-W2Vec  | SVM-rbf |   0.01  |         None         | 0.4802172889537464 | 0.483111286553
| TFIDF-W2Vec | SVM-rbf |  0.0001 |         None         |        0.5         |        0.5
+-------------+---------+---------+----------------------+--------------------+---------------
```