Logistic-Regression

September 25, 2018

1 Objective :

Apply logistic regression on Amazon review dataset to find accuracy and error of diffrent models.

1.1 Workflow:

1. Sort data based on time.
2. Split data into train and test.
3. Convert reviews of "Amazon Fine Food Review" dataset into vectors using :-
    - Bag of words.
    - TF-IDF
    - Average Word2vec
    - TF-IDF Word2ves
4. Perform standardization on every vectorized data.
5. Find best hyperparameter(lamda) by GridSearchCV and RandomizedSearchCV.
6. Apply Logistic Regression in diffrent models using L1 and L2 regularizer.
7. Find accuracy and error of the model.
8. Print confusion matrix and plot error plots for every model.
9. Find colinearity between features.
10. Find top n important feature as per their weight vector.

```
In [1]: %matplotlib inline

        import sqlite3
        import pandas as pd
        import numpy as np
        import nltk
        import matplotlib.pyplot as plt
        import seaborn as sns
        from sklearn.feature_extraction.text import TfidfTransformer
        from sklearn.feature_extraction.text import TfidfVectorizer
        import re, gensim
        import string
        from nltk.corpus import stopwords
        from nltk.stem.wordnet import WordNetLemmatizer
        from sklearn.feature_extraction.text import CountVectorizer
```

```
from sklearn.manifold import TSNE
from sklearn.preprocessing import StandardScaler
from sklearn.decomposition import TruncatedSVD
from sklearn.cross_validation import train_test_split
from sklearn.neighbors import KNeighborsClassifier
from sklearn.metrics import accuracy_score
from sklearn.cross_validation import cross_val_score
from collections import Counter
from sklearn.metrics import accuracy_score, f1_score, make_scorer
from sklearn import cross_validation
from sklearn.metrics import classification_report, confusion_matrix
from sklearn.naive_bayes import BernoulliNB
from sklearn.feature_selection import chi2, mutual_info_classif
from sklearn.feature_selection import mutual_info_classif
from sklearn.grid_search import GridSearchCV
from sklearn.model_selection import RandomizedSearchCV
from sklearn.linear_model import LogisticRegression
from scipy.stats import uniform
import copy
```

```
/home/dev/anaconda3/lib/python3.6/site-packages/sklearn/cross_validation.py:41: DeprecationWarn
  "This module will be removed in 0.20.", DeprecationWarning)
/home/dev/anaconda3/lib/python3.6/site-packages/sklearn/grid_search.py:42: DeprecationWarning:
  DeprecationWarning)
```

1.2 Importing data

In [2]:
```
"""
Reading data from .sqlite file,
choosing only positive and negative reviews not neutral reviews.
"""
# using the SQLite Table to read data.
con = sqlite3.connect('database.sqlite')

#filtering only positive and negative reviews i.e.
# not taking into consideration those reviews with Score=3
filtered_data = pd.read_sql_query("SELECT * FROM Reviews WHERE Score != 3", con)

# Give reviews with Score>3 a positive rating, and reviews with a score<3 a negative r
def partition(x):
    if x < 3:
        return 'negative'
    return 'positive'

#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
```

1.3 Cleansing data

```
In [3]: """
        Below code snippet removes duplicate data from dataset that are repeatedly mentioned.
        """
        #Sorting data according to ProductId in ascending order
        sorted_data=filtered_data.sort_values('ProductId', axis=0, ascending=True,\
                                              inplace=False, kind='quicksort',\
                                              na_position='last')
        #Deduplication of entries
        final=sorted_data.drop_duplicates(subset={"UserId","ProfileName","Time","Text"},\
                                          keep='first', inplace=False)
        final=final[final.HelpfulnessNumerator<=final.HelpfulnessDenominator]
        final.shape

Out[3]: (364171, 10)

In [4]: """
        Sorting data on the basis of TIME
        """
        final = final[:100000]
        final = final.sort_values(by=['Time'], axis=0)
        final.shape

Out[4]: (100000, 10)
```

1.4 Text preprocessing

```
In [5]: """
        This code snippet does text preprocessing
        """
        def cleanhtml(sentence): #function to clean the word of any html-tags
            cleanr = re.compile('<.*?>')
            cleantext = re.sub(cleanr, ' ', sentence)
            return cleantext
        def cleanpunc(sentence): #function to clean the word of any punctuation or special cha
            cleaned = re.sub(r'[?|!|\'|"|#]',r'',sentence)
            cleaned = re.sub(r'[.|,|)|(|\|/]',r' ',cleaned)
            return  cleaned
        stop = set(stopwords.words('english')) #set of stopwords
        sno = nltk.stem.SnowballStemmer('english') #initialising the snowball stemmer
        final_text = []
        for index in range(len(final['Text'])):
            filtered_sentence=[]
            sent=cleanhtml(final['Text'].iloc[index]) # remove HTml tags
            for w in sent.split():
                for cleaned_words in cleanpunc(w).split():# clean punctuation marks from words
```

```
                    if((cleaned_words.isalpha()) & (len(cleaned_words)>2)):# verifying word mu
                        cleaned_words = cleaned_words.lower()
                        if(cleaned_words not in stop):# blocks stopwords
                            s=(sno.stem(cleaned_words))# stemming in process
                            filtered_sentence.append(s)
                        else:
                            continue
                    else:
                        continue
            str1 = " ".join(filtered_sentence) #final cleaned string of words
            final_text.append(str1)
```

```
In [6]: amazon_data_text = pd.Series(final_text)
        amazon_data_label = pd.Series(final['Score'])
        print(amazon_data_text.shape)
        print(amazon_data_label.shape)
```

```
(100000,)
(100000,)
```

```
In [7]: """
        Spliting sample data into train_data and test_data (75:25)
        """
        x_train, x_test, y_train, y_test = cross_validation.train_test_split(\
                                                                    amazon_data_text,\
                                                                    amazon_data_label
                                                                    test_size = 0.25,\
                                                                    random_state=0)
```

```
In [8]: print(y_test.value_counts())
```

```
positive    21253
negative     3747
Name: Score, dtype: int64
```

1.4.1 Bag of words.

```
In [27]: """
         This code snippet converts train data from text to vectors by BOW.
         """
         count_vect = CountVectorizer(analyzer='word', dtype = 'float64') #in scikit-learn
         bow_text_train_vector = count_vect.fit_transform(x_train)
         bow_text_train_vector = bow_text_train_vector
         bow_text_train_vector.shape
```

```
Out[27]: (75000, 32711)
```

In [28]:
```
"""
This code snippet converts test data from text to vectors by BOW.
"""
bow_text_test_vector = count_vect.transform(x_test)
bow_text_test_vector = bow_text_test_vector
print(bow_text_test_vector.shape)
```

```
(25000, 32711)
```

In [29]:
```
"""
Standardize both training and test data
"""
scale = StandardScaler(with_mean = False)
bow_text_train_vector = scale.fit_transform(bow_text_train_vector)
bow_text_test_vector  = scale.transform(bow_text_test_vector)
print("Train data shape :",bow_text_train_vector.shape)
print("Test data shape :",bow_text_test_vector.shape)
```

```
Train data shape : (75000, 32711)
Test data shape : (25000, 32711)
```

In [30]:
```
"""
This code snippet deals with GridSearchCV
"""
tuned_parameters = [{ 'C' : [10**-4, 10**-3, 10**-2,\
                             10**-1, 10**0, 10**1,\
                             10**2,10**3, 10**4]}]
f1_scorer = make_scorer(f1_score, pos_label="positive")
model = GridSearchCV(LogisticRegression(), tuned_parameters,\
                     scoring = f1_scorer, cv=5 )
model.fit(bow_text_train_vector, y_train)
print(model.best_estimator_)
print("F1 Score : ",model.score(bow_text_train_vector, y_train))
```

```
LogisticRegression(C=0.001, class_weight=None, dual=False, fit_intercept=True,
          intercept_scaling=1, max_iter=100, multi_class='ovr', n_jobs=1,
          penalty='l2', random_state=None, solver='liblinear', tol=0.0001,
          verbose=0, warm_start=False)
F1 Score :  0.9820719286586403
```

In [38]:
```
"""
This code snippet deals with RandomizedSearchCV
"""
parameters = { 'C' : uniform(10**-2,10**2)}
f1_scorer = make_scorer(f1_score, pos_label="positive")
model = RandomizedSearchCV(LogisticRegression(), parameters, scoring = f1_scorer, cv=5
```

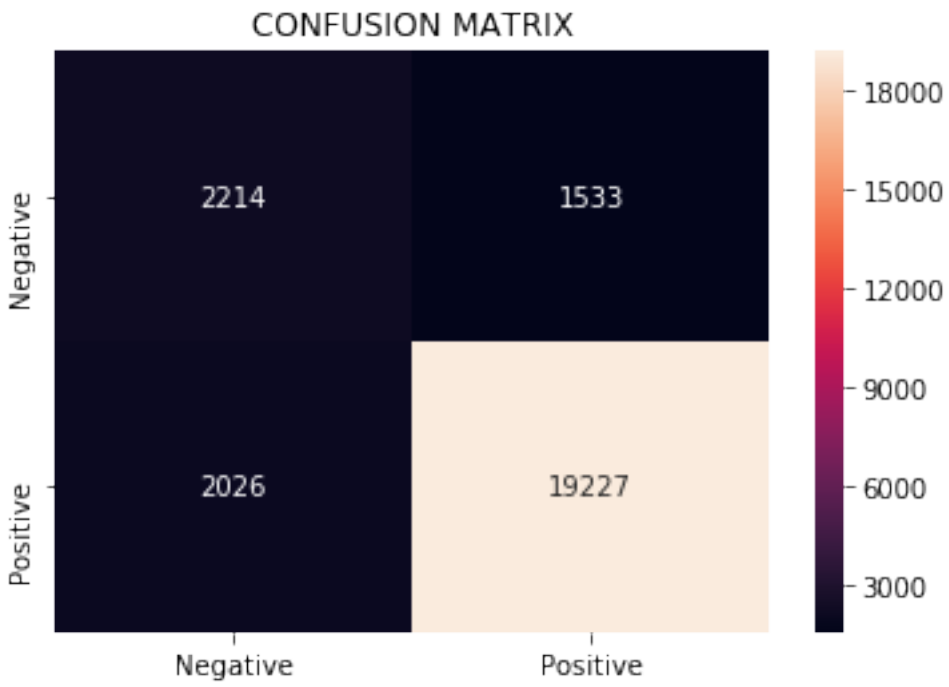
```
        model.fit(bow_text_train_vector, y_train)
        print(model.best_estimator_)
        print("F1 Score : ",model.score(bow_text_train_vector, y_train))
```

```
LogisticRegression(C=46.67064188978246, class_weight=None, dual=False,
          fit_intercept=True, intercept_scaling=1, max_iter=100,
          multi_class='ovr', n_jobs=1, penalty='l2', random_state=None,
          solver='liblinear', tol=0.0001, verbose=0, warm_start=False)
F1 Score :  0.9922409217222968
```

In [36]:
```
        """
        In this code snippet finds sparsity and erorr using lamda from GridSearchCV.
        """
        clf = LogisticRegression(C=1000, penalty='l2');
        clf.fit(bow_text_train_vector, y_train);
        w = clf.coef_
        print("Sparsity : ",np.count_nonzero(w))
        # response prediction
        pred = clf.predict(bow_text_test_vector)
        # evaluate error
        acc = accuracy_score(y_test, pred)*100
        print("Error : %.2f"%(100-acc))
        conf_matrix = confusion_matrix(y_test, pred)
        confusion_matrix_df = pd.DataFrame(conf_matrix,
                                           ["Negative", "Positive"],\
                                           ["Negative", "Positive"],\
                                           dtype=int)
        sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
        plt.title("CONFUSION MATRIX")
```

```
Sparsity :  32711
Error : 14.24
```

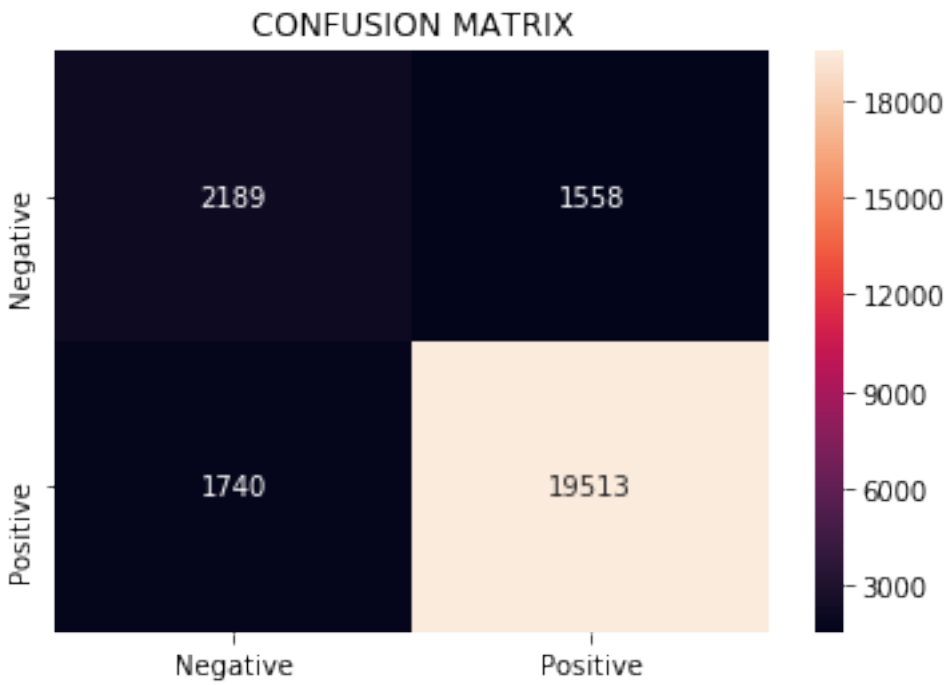
Out[36]:
```
Text(0.5,1,'CONFUSION MATRIX')
```



In [37]:
```
"""
In this code snippet finds sparsity and erorr using lamda from GridSearchCV.
"""
clf = LogisticRegression(C=1000, penalty='l1');
clf.fit(bow_text_train_vector, y_train);
w = clf.coef_
print("Sparsity : ",np.count_nonzero(w))
# response prediction
pred = clf.predict(bow_text_test_vector)
# evaluate error
acc = accuracy_score(y_test, pred)*100
print("Error : %.2f"%(100-acc))
conf_matrix = confusion_matrix(y_test, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Sparsity :  19941
Error : 13.19
```

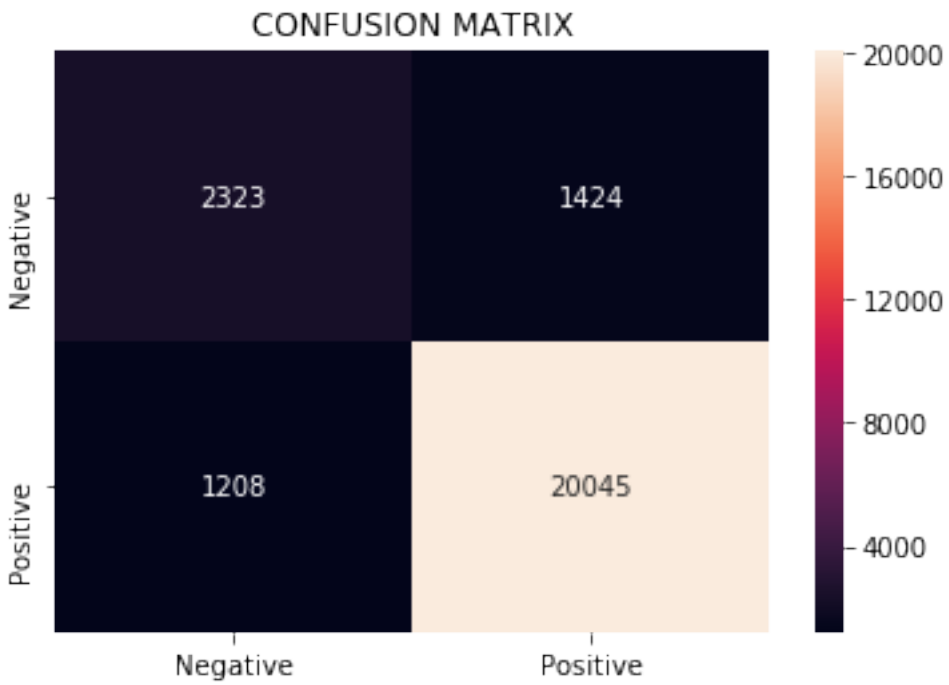
Out[37]: Text(0.5,1,'CONFUSION MATRIX')



In [47]:
```
"""
In this code snippet finds sparsity and erorr using lamda from RandomizedSearchCV.
"""
clf = LogisticRegression(C=0.02, penalty='l2');
clf.fit(bow_text_train_vector, y_train);
w = clf.coef_
print("Sparsity : ",np.count_nonzero(w))
# response prediction
pred = clf.predict(bow_text_test_vector)
# evaluate error
acc = accuracy_score(y_test, pred)*100
print("Error : %.2f"%(100-acc))
conf_matrix = confusion_matrix(y_test, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Sparsity :  32711
Error : 10.53
```

Out[47]:
```
Text(0.5,1,'CONFUSION MATRIX')
```

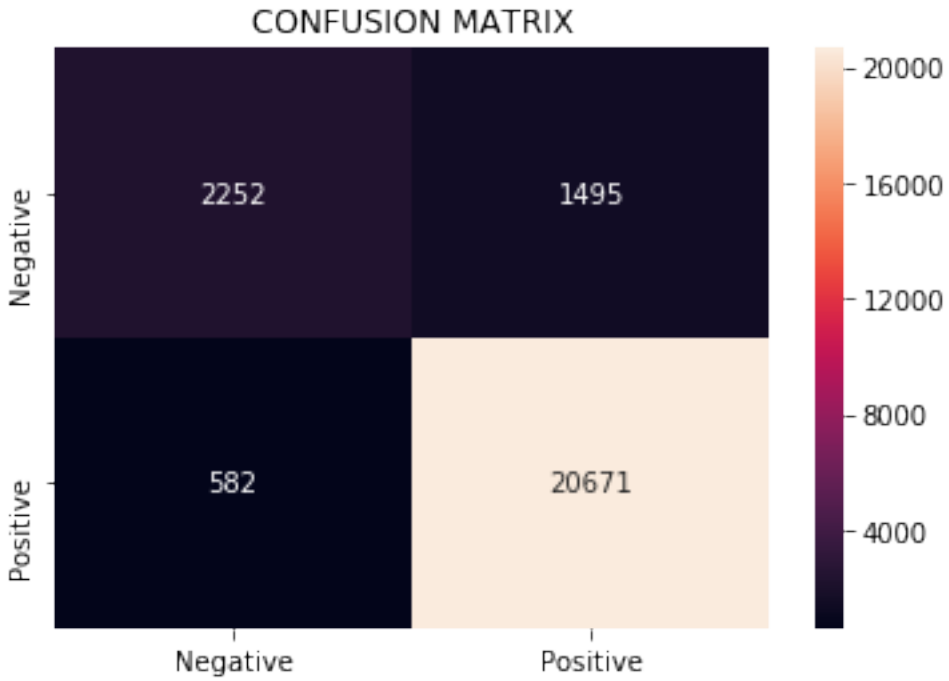


In [87]:
```
"""Lists to store lambda and error values"""
lambda_list = [0.02,0.002,0.0002]
train_error = []
test_error = []
```

In [88]:
```
"""
In this code snippet finds sparsity and test erorr using lamda from RandomizedSearchC
"""
clf = LogisticRegression(C=0.02, penalty='l1');
clf.fit(bow_text_train_vector, y_train);
w = clf.coef_
print("Sparsity : ",np.count_nonzero(w))
# response prediction
pred = clf.predict(bow_text_test_vector)
# evaluate error
acc = accuracy_score(y_test, pred)*100
print("Error : %.2f"%(100-acc))
test_error.append(100-acc)
conf_matrix = confusion_matrix(y_test, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Sparsity :  6351
Error : 8.31
```

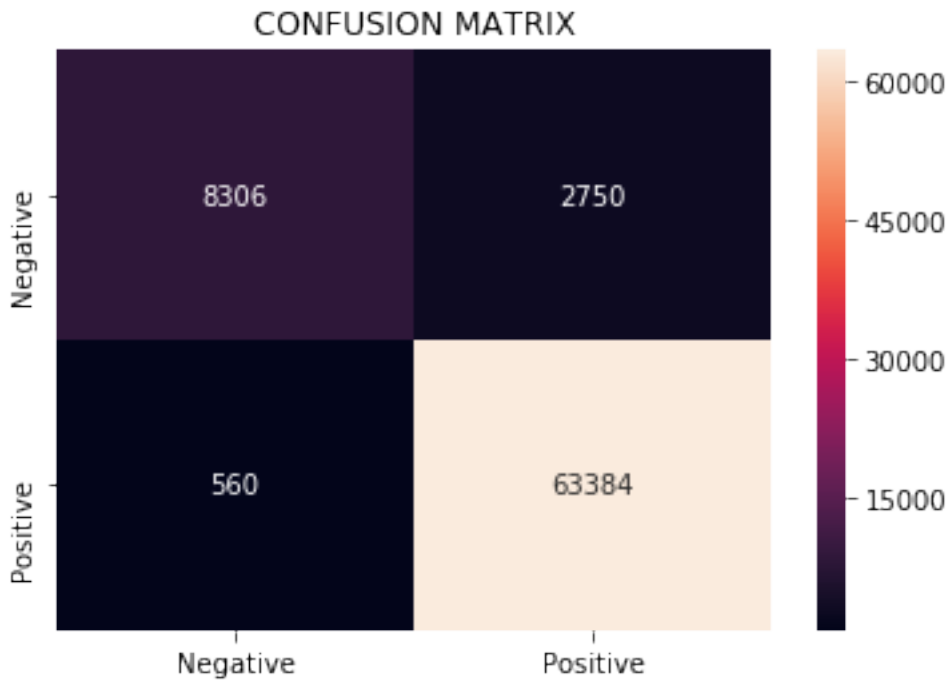
Out[88]: Text(0.5,1,'CONFUSION MATRIX')



In [89]:
```
"""
In this code snippet finds sparsity and train erorr using lamda value from Randomized
"""
# response prediction
pred = clf.predict(bow_text_train_vector)
# evaluate error
acc = accuracy_score(y_train, pred)*100
print("Error : %.2f"%(100-acc))
train_error.append(100-acc)
conf_matrix = confusion_matrix(y_train, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Error : 4.41
```

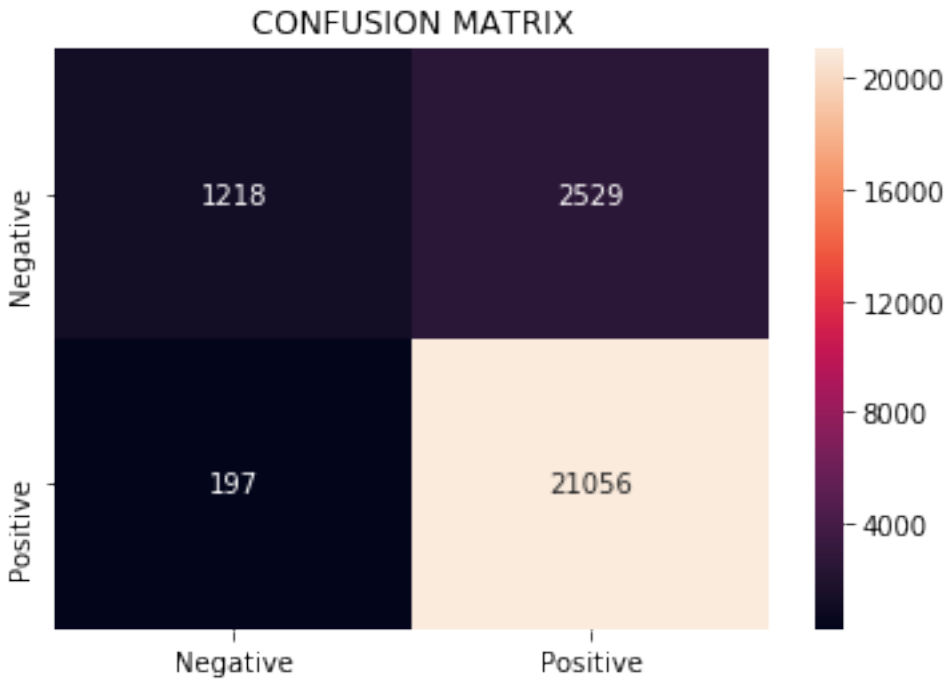
Out[89]: Text(0.5,1,'CONFUSION MATRIX')



In [90]:
```
"""
In this code snippet finds sparsity and test erorr using lamda from RandomizedSearchC
"""
clf = LogisticRegression(C=0.002, penalty='l1');
clf.fit(bow_text_train_vector, y_train);
w = clf.coef_
print("Sparsity : ",np.count_nonzero(w))
# response prediction
pred = clf.predict(bow_text_test_vector)
# evaluate error
acc = accuracy_score(y_test, pred)*100
print("Error : %.2f"%(100-acc))
test_error.append(100-acc)
conf_matrix = confusion_matrix(y_test, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Sparsity :  216
Error : 10.90
```

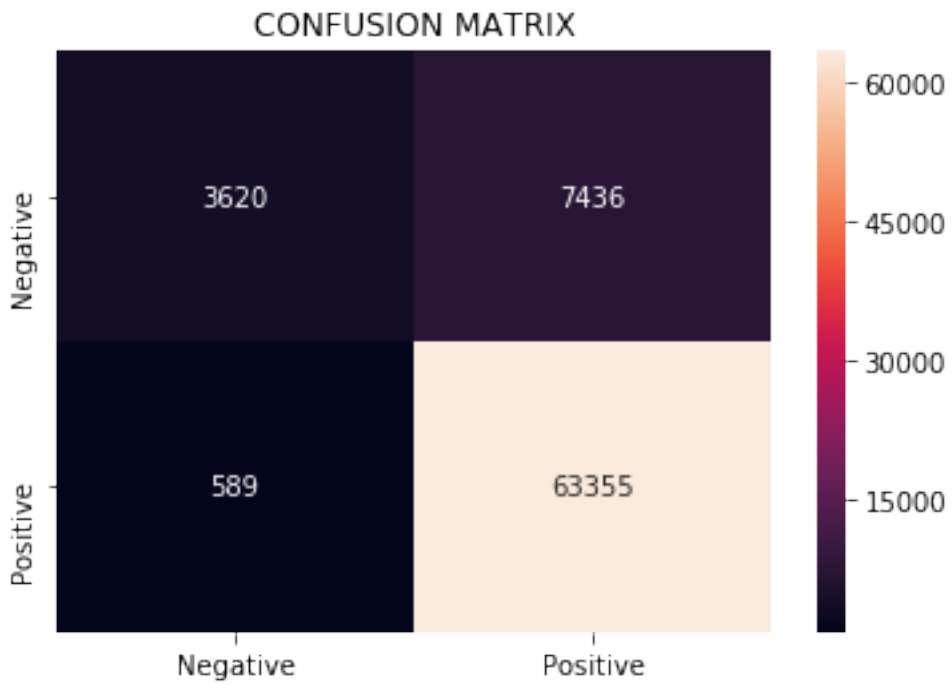
Out[90]: Text(0.5,1,'CONFUSION MATRIX')



In [91]:
```
"""
In this code snippet finds sparsity and train erorr using lamda value from Randomized
"""
# response prediction
pred = clf.predict(bow_text_train_vector)
# evaluate error
acc = accuracy_score(y_train, pred)*100
print("Error : %.2f"%(100-acc))
train_error.append(100-acc)
conf_matrix = confusion_matrix(y_train, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Error : 10.70
```

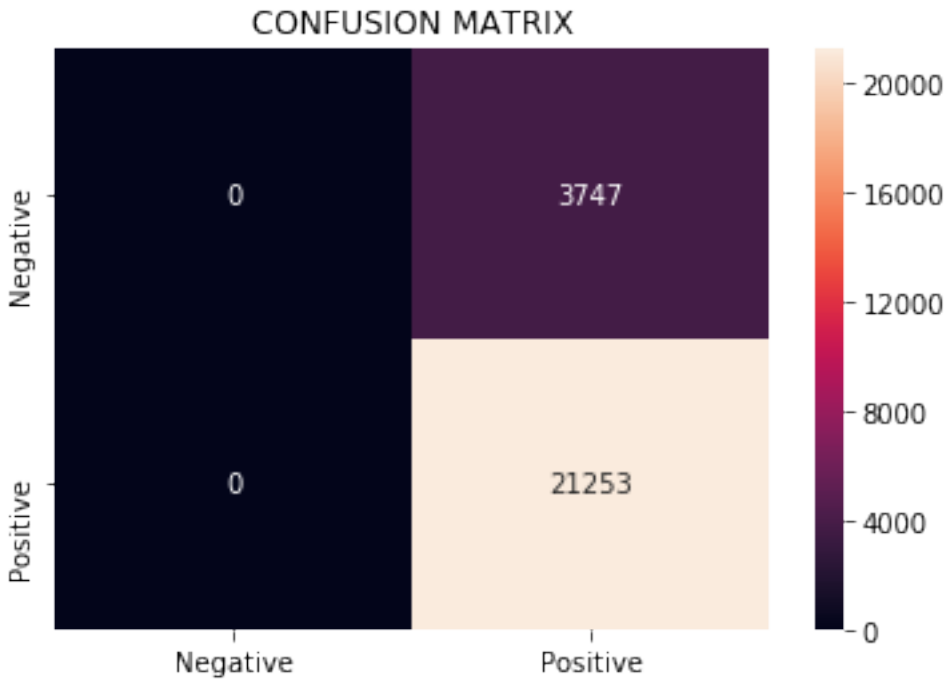
Out[91]: Text(0.5,1,'CONFUSION MATRIX')



In [92]:
```
"""
In this code snippet finds sparsity and test erorr using lamda from RandomizedSearchC
"""
clf = LogisticRegression(C=0.0002, penalty='l1');
clf.fit(bow_text_train_vector, y_train);
w = clf.coef_
print("Sparsity : ",np.count_nonzero(w))
# response prediction
pred = clf.predict(bow_text_test_vector)
# evaluate error
acc = accuracy_score(y_test, pred)*100
print("Error : %.2f"%(100-acc))
test_error.append(100-acc)
conf_matrix = confusion_matrix(y_test, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Sparsity :  2
Error : 14.99
```

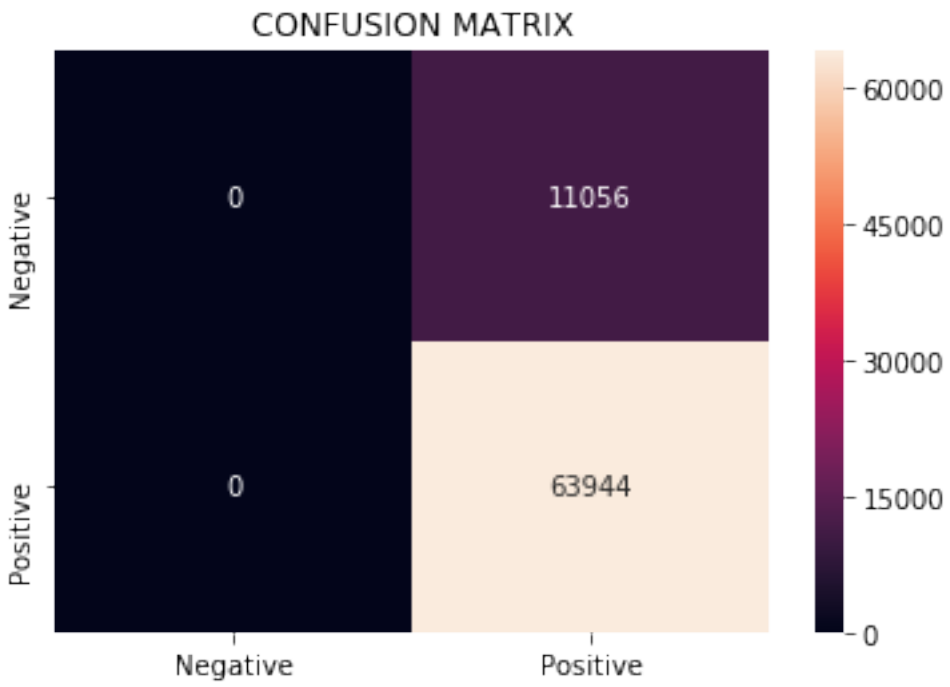
Out[92]: Text(0.5,1,'CONFUSION MATRIX')



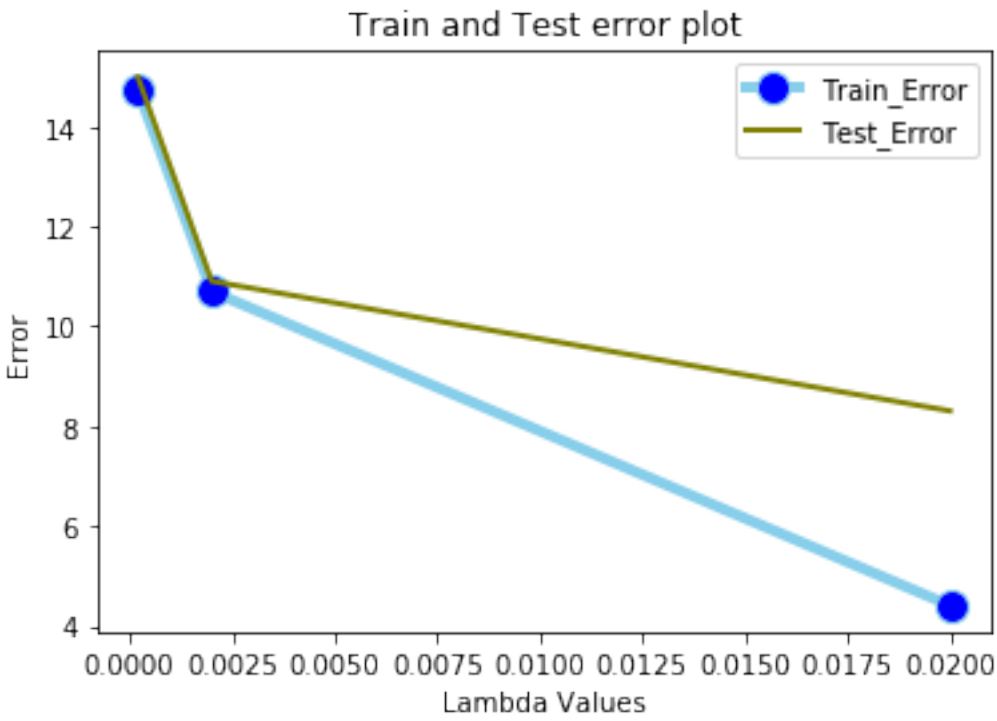
In [93]:
```
"""
In this code snippet finds sparsity and train erorr using lamda value from Randomized
"""
# response prediction
pred = clf.predict(bow_text_train_vector)
# evaluate error
acc = accuracy_score(y_train, pred)*100
print("Error : %.2f"%(100-acc))
train_error.append(100-acc)
conf_matrix = confusion_matrix(y_train, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Error : 14.74
```

Out[93]: Text(0.5,1,'CONFUSION MATRIX')




```
In [114]: Train_Error, = plt.plot( lambda_list, train_error, marker='o',\
                                  markerfacecolor='blue', markersize=12,\
                                  color='skyblue', linewidth=4)
          Test_Error,  = plt.plot( lambda_list, test_error, marker='',\
                                  color='olive', linewidth=2)
          plt.xlabel('Lambda Values')
          plt.ylabel('Error')
          plt.title('Train and Test error plot')
          plt.legend([Train_Error,Test_Error], ["Train_Error","Test_Error"])
          plt.show()
```



In [51]:
```
"""
This code snippet shows effect of colinearity of on weight vectors
"""
x = copy.deepcopy(bow_text_train_vector)

clf = LogisticRegression(C=0.02, penalty='l1');
clf.fit(bow_text_train_vector, y_train);
w = clf.coef_
a = np.transpose(np.nonzero(w))
print("Weight vector before perturbation :", end=" ")
for i,j in a[:20]:
    print("%.5f"%w[i,j], end=" ")

print("\n")

# perturbation technique start
epsilon = np.random.normal(loc=0.0, scale=0.01)
a = np.transpose(np.nonzero(x))
for i,j in a:
    x[i,j] += epsilon
# perturbation technique end

clf = LogisticRegression(C=0.02, penalty='l1');
clf.fit(x, y_train);
```

```
        w = clf.coef_
        a = np.transpose(np.nonzero(w))
        print("Weight vector after perturbation :", end=" ")
        for i,j in a[:20]:
            print("%.5f"%w[i,j], end=" ")

        # deleting the variable to free RAM
        del x
```

```
Weight vector before perturbation : 0.00113 0.00005 -0.02143 0.00931 0.00431 -0.00209 -0.01079

Weight vector after perturbation : 0.00304 -0.02144 0.00932 0.00430 -0.00209 -0.01079 0.00250
```

```
In [72]: """
         This code snippet prints top 10 important features along with there index no
         """
         clf = LogisticRegression(C=0.02, penalty='l1');
         clf.fit(bow_text_train_vector, y_train);
         w = clf.coef_
         a = [i for i in sorted(enumerate(w[0]),key=lambda pair: pair[1], reverse = True) if i
         print("FeatureIndex  FeatureWeight\n")
         print(*a[:10],sep = '\n')
```

```
FeatureIndex  FeatureWeight

(12204, 0.7289452936016304)
(16718, 0.5963629686574519)
(2604, 0.5603180499523812)
(7368, 0.44692751917682194)
(11931, 0.3870590135613957)
(21179, 0.3845441773177839)
(9631, 0.38398177379327353)
(19256, 0.26993894477896646)
(899, 0.26085363814539275)
(10053, 0.25132080217345454)
```

Observation :

- Here we have applied Bag of words to convert text to vector.
- We got hyperparameter(lambda) from GridSearchCV is 0.001 and from RandomizedSearchCV is 46.67.
- I got best result from a model where C = 0.02 (i.e. lambda = 46.67), sparsity = 6351 and the minimum test error 8.31.
- Colinearity is also not affecting much to features.

1.4.2 TF IDF.

```
In [22]: """
         This code snippet converts train data from text to vectors by TF_IDF.
```

```
        """
        tf_idf_vect = TfidfVectorizer(ngram_range=(1,2))
        final_tf_idf_train = tf_idf_vect.fit_transform(x_train)
        final_tf_idf_train.shape
```

```
Out[22]: (75000, 1002260)
```

```
In [23]: """
         This code snippet converts test data from text to vectors by TF_IDF.
         """
         final_tf_idf_test = tf_idf_vect.transform(x_test)
         final_tf_idf_test.shape
```

```
Out[23]: (25000, 1002260)
```

```
In [24]: """
         Standardize both training and test data
         """
         scale = StandardScaler(with_mean = False)
         final_tf_idf_train = scale.fit_transform(final_tf_idf_train)
         final_tf_idf_test  = scale.transform(final_tf_idf_test)
         print("Train data shape : ",final_tf_idf_train.shape)
         print("Test data shape : ",final_tf_idf_test.shape)
```

```
Train data shape :  (75000, 1002260)
Test data shape :  (25000, 1002260)
```

```
In [25]: """
         This code snippet deals with GridSearchCV
         """
         tuned_parameters = [{ 'C' : [10**-4, 10**-3, 10**-2,\
                                      10**-1, 10**0, 10**1,\
                                      10**2,10**3, 10**4]}]
         f1_scorer = make_scorer(f1_score, pos_label="positive")
         model = GridSearchCV(LogisticRegression(), tuned_parameters, scoring = f1_scorer, cv=5
         model.fit(final_tf_idf_train, y_train)
         print(model.best_estimator_)
         print("F1 Score : ",model.score(final_tf_idf_train, y_train))
```

```
LogisticRegression(C=1000, class_weight=None, dual=False, fit_intercept=True,
          intercept_scaling=1, max_iter=100, multi_class='ovr', n_jobs=1,
          penalty='l2', random_state=None, solver='liblinear', tol=0.0001,
          verbose=0, warm_start=False)
F1 Score :  1.0
```

```
In [41]: """
         This code snippet deals with RandomizedSearchCV
```

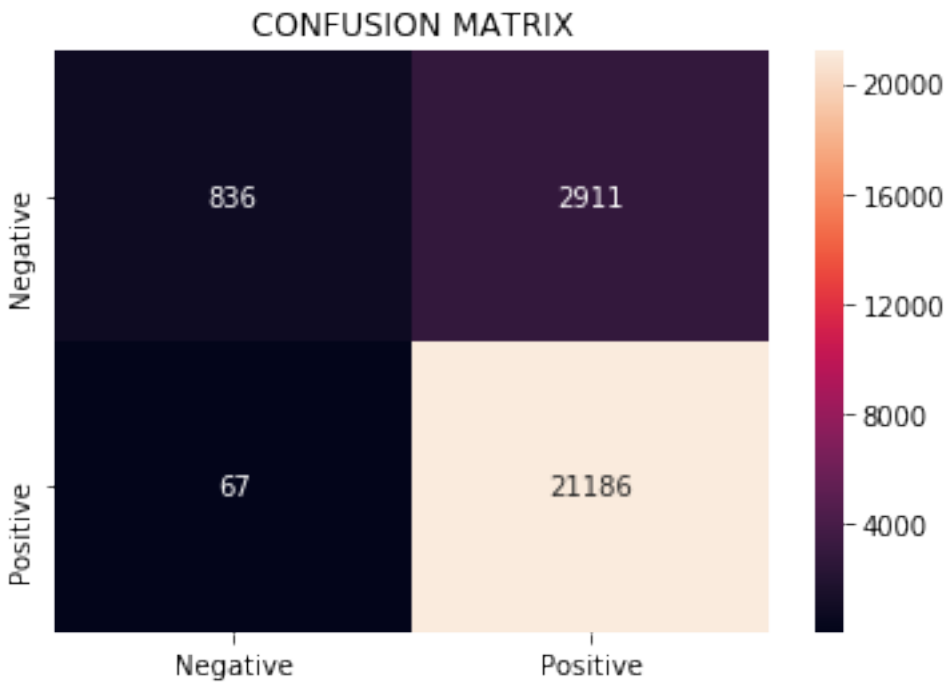
```
        """
        parameters = { 'C' : uniform(10**-2,10**2)}
        f1_scorer = make_scorer(f1_score, pos_label="positive")
        model = RandomizedSearchCV(LogisticRegression(), parameters, scoring = f1_scorer, cv=5
        model.fit(final_tf_idf_train, y_train)
        print(model.best_estimator_)
        print("F1 Score : ",model.score(final_tf_idf_train, y_train))
```

```
LogisticRegression(C=59.673280620372125, class_weight=None, dual=False,
          fit_intercept=True, intercept_scaling=1, max_iter=100,
          multi_class='ovr', n_jobs=1, penalty='l2', random_state=None,
          solver='liblinear', tol=0.0001, verbose=0, warm_start=False)
F1 Score :  1.0
```

In [39]:
```
        """
        In this code snippet finds sparsity and erorr using lamda from GridSearchCV.
        """
        clf = LogisticRegression(C=0.001, penalty='l2');
        clf.fit(final_tf_idf_train, y_train);
        w = clf.coef_
        print("Sparsity : ",np.count_nonzero(w))
        # response prediction
        pred = clf.predict(final_tf_idf_test)
        # evaluate error
        acc = accuracy_score(y_test, pred)*100
        print("Error : %.2f"%(100-acc))
        conf_matrix = confusion_matrix(y_test, pred)
        confusion_matrix_df = pd.DataFrame(conf_matrix,
                                           ["Negative", "Positive"],\
                                           ["Negative", "Positive"],\
                                           dtype=int)
        sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
        plt.title("CONFUSION MATRIX")
```

```
Sparsity :  1002260
Error : 11.91
```

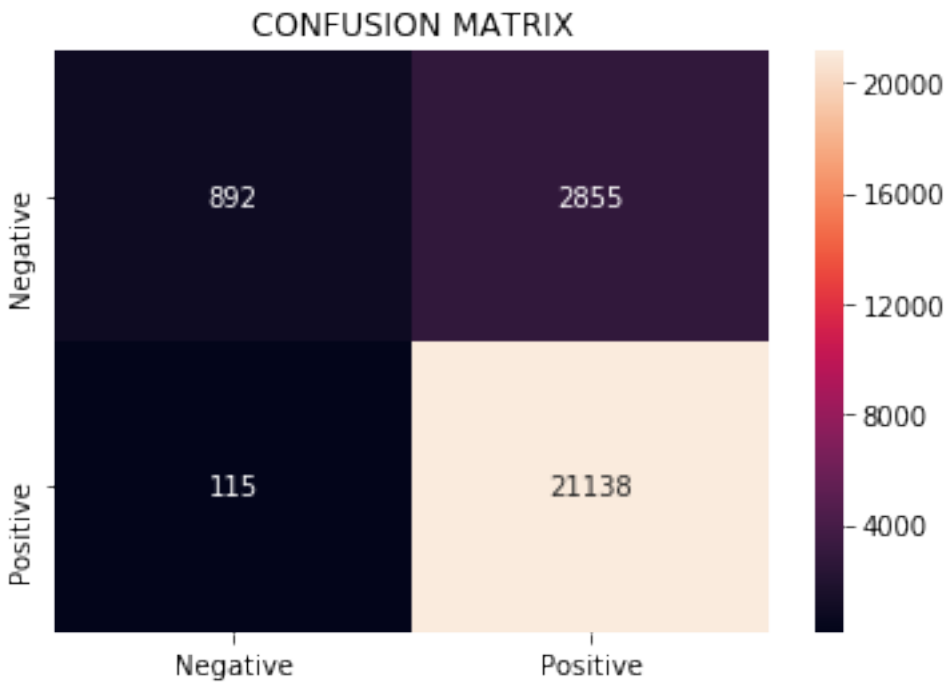
Out[39]:
```
Text(0.5,1,'CONFUSION MATRIX')
```



In [40]:
```
"""
In this code snippet finds sparsity and erorr using lamda from GridSearchCV.
"""
clf = LogisticRegression(C=0.001, penalty='l1');
clf.fit(final_tf_idf_train, y_train);
w = clf.coef_
print("Sparsity : ",np.count_nonzero(w))
# response prediction
pred = clf.predict(final_tf_idf_test)
# evaluate error
acc = accuracy_score(y_test, pred)*100
print("Error : %.2f"%(100-acc))
conf_matrix = confusion_matrix(y_test, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Sparsity :  108
Error : 11.88
```

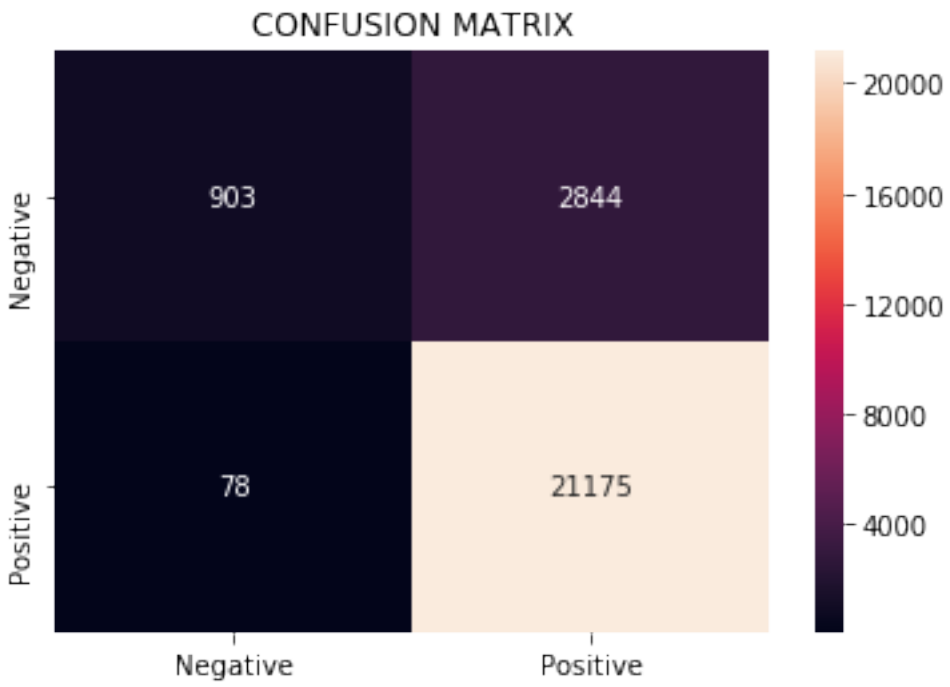
Out[40]:
```
Text(0.5,1,'CONFUSION MATRIX')
```



In [53]:
```
"""
In this code snippet finds sparsity and erorr using lamda from RandomizedSearchCV.
"""
clf = LogisticRegression(C=0.016, penalty='l2');
clf.fit(final_tf_idf_train, y_train);
w = clf.coef_
print("Sparsity : ",np.count_nonzero(w))
# response prediction
pred = clf.predict(final_tf_idf_test)
# evaluate error
acc = accuracy_score(y_test, pred)*100
print("Error : %.2f"%(100-acc))
conf_matrix = confusion_matrix(y_test, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Sparsity :  1002260
Error : 11.69
```

Out[53]: Text(0.5,1,'CONFUSION MATRIX')

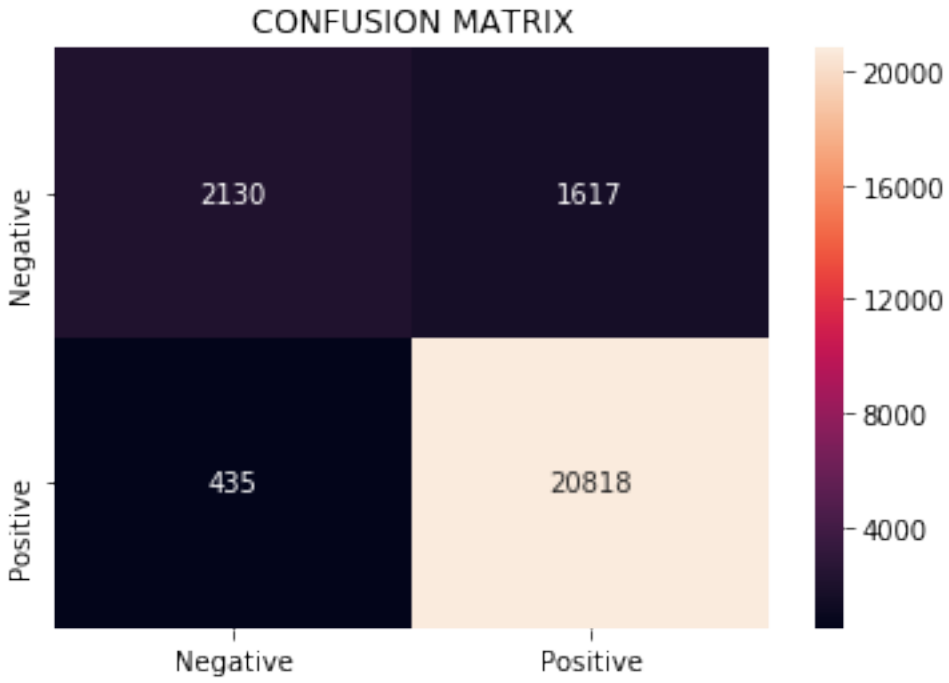


In [156]:
```
"""Lists to store lambda and error values"""
lambda_list = [0.02,0.002,0.0002]
train_error = []
test_error = []
```

In [157]:
```
"""
In this code snippet finds sparsity and erorr using lamda from RandomizedSearchCV.
"""
clf = LogisticRegression(C=0.016, penalty='l1');
clf.fit(final_tf_idf_train, y_train);
w = clf.coef_
print("Sparsity : ",np.count_nonzero(w))
# response prediction
pred = clf.predict(final_tf_idf_test)
# evaluate error
acc = accuracy_score(y_test, pred)*100
print("Error : %.2f"%(100-acc))
train_error.append(100-acc)
conf_matrix = confusion_matrix(y_test, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Sparsity :  32487
Error : 8.21
```

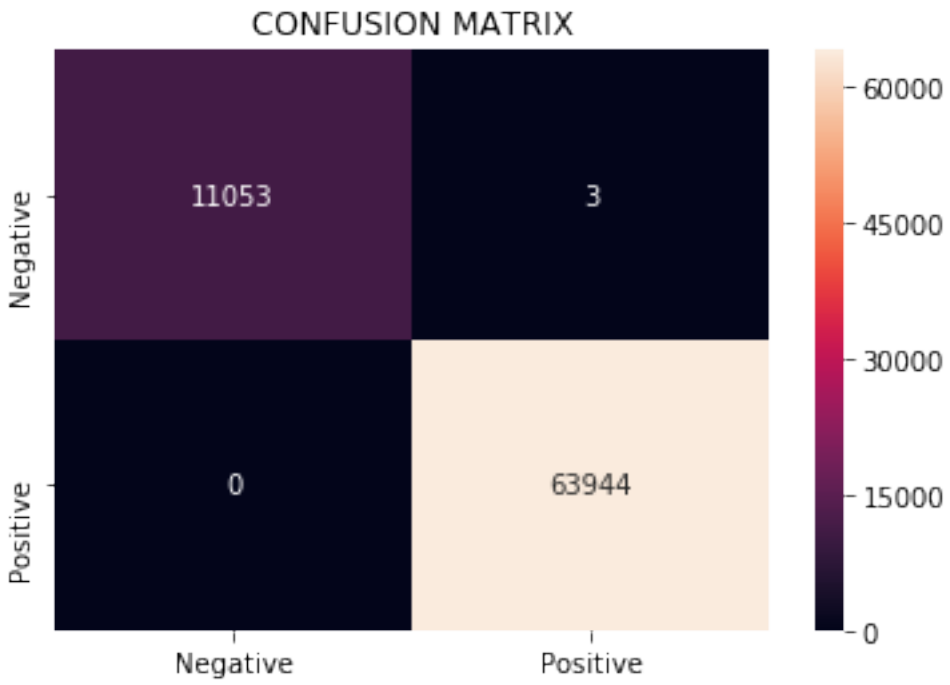
Out[157]: Text(0.5,1,'CONFUSION MATRIX')



In [158]:
```
"""
In this code snippet finds sparsity and train erorr using lamda value from Randomize
"""
# response prediction
pred = clf.predict(final_tf_idf_train)
# evaluate error
acc = accuracy_score(y_train, pred)*100
print("Error : %.2f"%(100-acc))
test_error.append(100-acc)
conf_matrix = confusion_matrix(y_train, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Error : 0.00
```

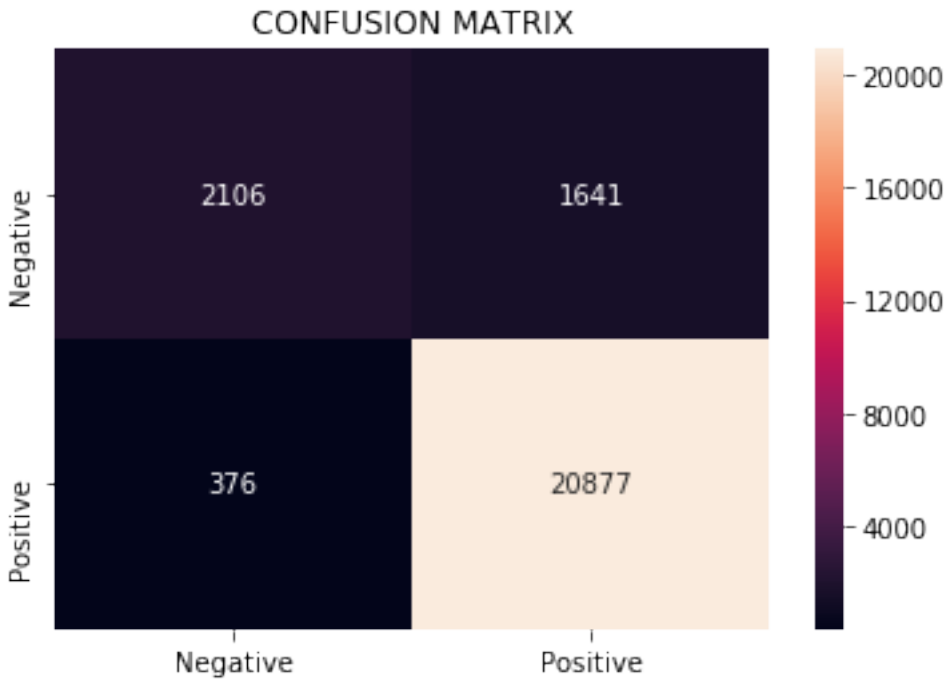
Out[158]: Text(0.5,1,'CONFUSION MATRIX')



In [159]:
```
"""
In this code snippet finds sparsity and erorr using lamda from RandomizedSearchCV.
"""
clf = LogisticRegression(C=0.005, penalty='l1');
clf.fit(final_tf_idf_train, y_train);
w = clf.coef_
print("Sparsity : ",np.count_nonzero(w))
# response prediction
pred = clf.predict(final_tf_idf_test)
# evaluate error
acc = accuracy_score(y_test, pred)*100
print("Error : %.2f"%(100-acc))
train_error.append(100-acc)
conf_matrix = confusion_matrix(y_test, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Sparsity :  10722
Error : 8.07
```

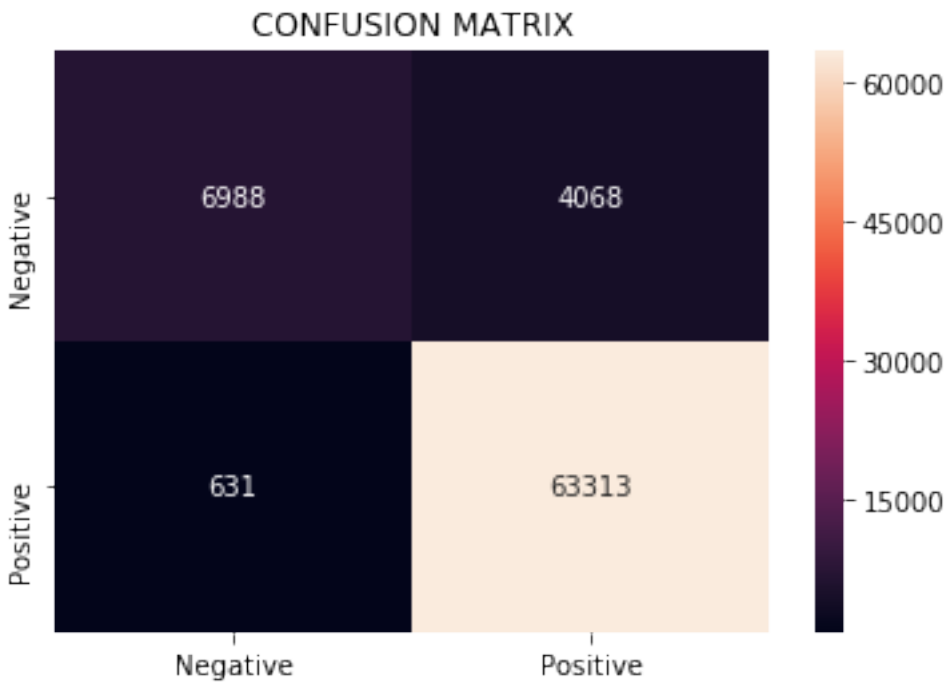
Out[159]: Text(0.5,1,'CONFUSION MATRIX')



In [160]:
```
"""
In this code snippet finds sparsity and train erorr using lamda value from Randomize
"""
# response prediction
pred = clf.predict(final_tf_idf_train)
# evaluate error
acc = accuracy_score(y_train, pred)*100
print("Error : %.2f"%(100-acc))
test_error.append(100-acc)
conf_matrix = confusion_matrix(y_train, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Error : 6.27
```

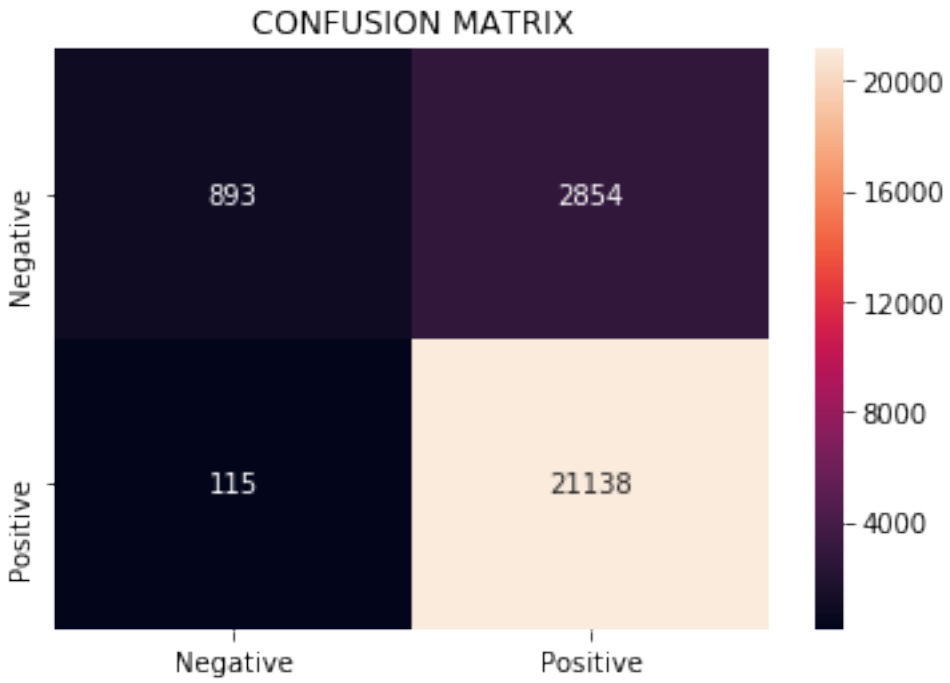
Out[160]: Text(0.5,1,'CONFUSION MATRIX')



In [161]:
```
"""
In this code snippet finds sparsity and erorr using lamda from RandomizedSearchCV.
"""
clf = LogisticRegression(C=0.001, penalty='l1');
clf.fit(final_tf_idf_train, y_train);
w = clf.coef_
print("Sparsity : ",np.count_nonzero(w))
# response prediction
pred = clf.predict(final_tf_idf_test)
# evaluate error
acc = accuracy_score(y_test, pred)*100
print("Error : %.2f"%(100-acc))
train_error.append(100-acc)
conf_matrix = confusion_matrix(y_test, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Sparsity :  108
Error : 11.88
```

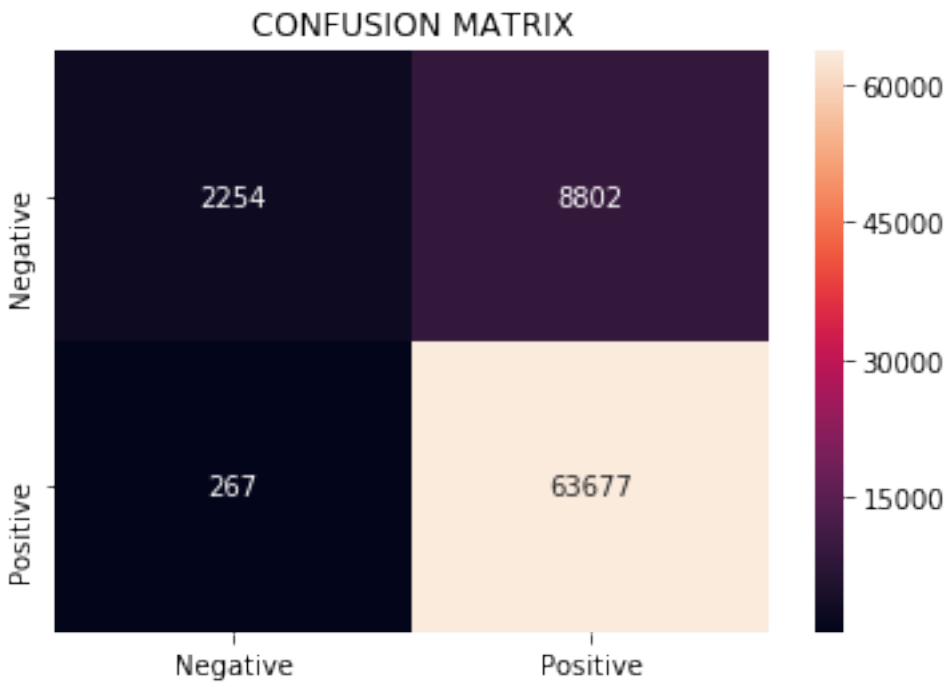
Out[161]: Text(0.5,1,'CONFUSION MATRIX')



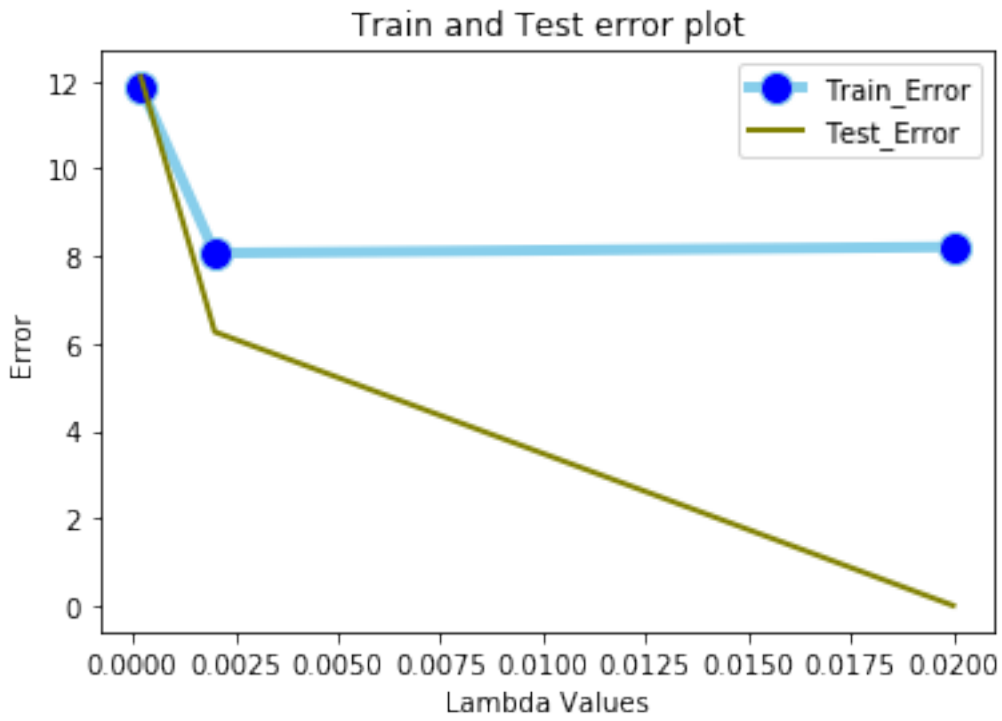
In [162]:
```
"""
In this code snippet finds sparsity and train erorr using lamda value from Randomize
"""
# response prediction
pred = clf.predict(final_tf_idf_train)
# evaluate error
acc = accuracy_score(y_train, pred)*100
print("Error : %.2f"%(100-acc))
test_error.append(100-acc)
conf_matrix = confusion_matrix(y_train, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Error : 12.09
```

Out[162]: Text(0.5,1,'CONFUSION MATRIX')




```
In [163]: Train_Error, = plt.plot( lambda_list, train_error, marker='o',\
                                  markerfacecolor='blue', markersize=12,\
                                  color='skyblue', linewidth=4)
          Test_Error,  = plt.plot( lambda_list, test_error, marker='',\
                                  color='olive', linewidth=2)
          plt.xlabel('Lambda Values')
          plt.ylabel('Error')
          plt.title('Train and Test error plot')
          plt.legend([Train_Error,Test_Error], ["Train_Error","Test_Error"])
          plt.show()
```



In [57]:
```
"""
This code snippet shows effect of colinearity of on weight vectors
"""
x = copy.deepcopy(final_tf_idf_train)

clf = LogisticRegression(C=0.016, penalty='l1');
clf.fit(final_tf_idf_train, y_train);
w = clf.coef_
a = np.transpose(np.nonzero(w))
print("Weight vector before perturbation :", end=" ")
for i,j in a[:20]:
    print("%.5f"%w[i,j], end=" ")

print("\n")

# perturbation technique start
epsilon = np.random.normal(loc=0.0, scale=0.01)
a = np.transpose(np.nonzero(x))
for i,j in a:
    x[i,j] += epsilon
# perturbation technique end

clf = LogisticRegression(C=0.016, penalty='l1');
clf.fit(x, y_train);
```

```
        w = clf.coef_
        a = np.transpose(np.nonzero(w))
        print("Weight vector after perturbation :", end=" ")
        for i,j in a[:20]:
            print("%.5f"%w[i,j], end=" ")

        # deleting the variable to free RAM
        del x
```

```
Weight vector before perturbation : -0.00000 0.00063 -0.00002 -0.00190 -0.00002 -0.00111 -0.000

Weight vector after perturbation : 0.00001 0.00045 -0.00019 -0.00011 -0.00029 -0.00049 -0.00003
```

```
In [58]: """
         This code snippet prints top 10 important features along with there index no
         """
         clf = LogisticRegression(C=0.016, penalty='l1');
         clf.fit(final_tf_idf_train, y_train);
         w = clf.coef_
         a = [i for i in sorted(enumerate(w[0]),key=lambda pair: pair[1], reverse = True) if i
         print("FeatureIndex  FeatureWeight\n")
         print(*a[:10],sep = '\n')
```

```
FeatureIndex  FeatureWeight

(387933, 0.785934372969754)
(516162, 0.6364985687573737)
(78206, 0.5743342190942607)
(230440, 0.4394084060182864)
(377923, 0.3935776519903513)
(641873, 0.3700703693077426)
(298018, 0.33521021298916326)
(418383, 0.30591197107353496)
(584950, 0.25422810437674453)
(316225, 0.24908671617036693)
```

Observation:

- Here we have applied TF IDF to convert text to vector.
- We got hyperparameter(lambda) from GridSearchCV is 1000 and from RandomizedSearchCV is 59.67 .
- I got best result from a model where C = 0.016 (i.e. lambda = 59.67), sparsity = 32846 and the minimum error 8.21 .
- Colinearity is also not affecting much to features.

1.5 3) Word2Vec

```
In [10]: """
         Creating own vocabulary of words from reviews.
```

```
"""
i=0
list_of_train_sent=[]
for sent in x_train:
    filtered_sentence=[]
    sent=cleanhtml(sent)
    for w in sent.split():
        for cleaned_words in cleanpunc(w).split():
            if(cleaned_words.isalpha()):
                filtered_sentence.append(cleaned_words.lower())
            else:
                continue
    list_of_train_sent.append(filtered_sentence)
w2v_train_model=gensim.models.Word2Vec(list_of_train_sent,
                                       min_count=5,size=50,
                                       workers=4)
i=0
list_of_test_sent=[]
for sent in x_test:
    filtered_sentence=[]
    sent=cleanhtml(sent)
    for w in sent.split():
        for cleaned_words in cleanpunc(w).split():
            if(cleaned_words.isalpha()):
                filtered_sentence.append(cleaned_words.lower())
            else:
                continue
    list_of_test_sent.append(filtered_sentence)
w2v_test_model=gensim.models.Word2Vec(list_of_test_sent,min_count=5,size=50, workers=
```

1.5.1 a) Average Word2Vec

```
In [17]: """
         This code snippet converts train data from text to vectors by Average Word2Vec
         """
         # compute average word2vec for each review.
         tain_vectors = []; # the avg-w2v for each sentence/review is stored in this list
         for sent in list_of_train_sent: # for each review/sentence
             sent_vec = np.zeros(50) # as word vectors are of zero length
             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
                 try:
                     vec = w2v_train_model.wv[word]
                     sent_vec += vec
                     cnt_words += 1
                 except:
                     pass
             if cnt_words == 0:
```

```
            cnt_words = 1
        sent_vec /= cnt_words
        tain_vectors.append(sent_vec)
    train_avg_w2v = np.asmatrix(tain_vectors)
    train_avg_w2v.shape
```

```
Out[17]: (75000, 50)
```

```
In [18]: """
         This code snippet converts test data from text to vectors by Average Word2Vec
         """
         # compute average word2vec for each review.
         test_vectors = []; # the avg-w2v for each sentence/review is stored in this list
         for sent in list_of_test_sent: # for each review/sentence
             sent_vec = np.zeros(50) # as word vectors are of zero length
             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
                 try:
                     vec = w2v_test_model.wv[word]
                     sent_vec += vec
                     cnt_words += 1
                 except:
                     pass
             if cnt_words == 0:
                 cnt_words = 1
             sent_vec /= cnt_words
             test_vectors.append(sent_vec)
         test_avg_w2v = np.asmatrix(test_vectors)
         test_avg_w2v.shape
```

```
Out[18]: (25000, 50)
```

```
In [19]: """
         Standardize both training and test data
         """
         scale = StandardScaler(with_mean = False)
         train_avg_w2v = scale.fit_transform(train_avg_w2v)
         test_avg_w2v  = scale.transform(test_avg_w2v)
         print("Train data shape : ",train_avg_w2v.shape)
         print("Test data shape : ",test_avg_w2v.shape)
```

```
Train data shape :  (75000, 50)
Test data shape :  (25000, 50)
```

```
In [32]: import pickle
         pickle_out = open("train_avg_w2v.pkl", "wb")
         pickle.dump(train_avg_w2v, pickle_out)
         pickle_out.close()
```

```
        pickle_out = open("test_avg_w2v.pkl", "wb")
        pickle.dump(test_avg_w2v, pickle_out)
        pickle_out.close()
```

```
In [20]: """
         This code snippet deals with GridSearchCV
         """
         tuned_parameters = [{ 'C' : [10**-4, 10**-3, 10**-2,\
                                      10**-1, 10**0, 10**1,\
                                      10**2,10**3, 10**4]}]
         f1_scorer = make_scorer(f1_score, pos_label="positive")
         model = GridSearchCV(LogisticRegression(), tuned_parameters, scoring = f1_scorer, cv=5
         model.fit(train_avg_w2v, y_train)
         print(model.best_estimator_)
         print("F1 Score : ",model.score(train_avg_w2v, y_train))
```

```
LogisticRegression(C=1, class_weight=None, dual=False, fit_intercept=True,
          intercept_scaling=1, max_iter=100, multi_class='ovr', n_jobs=1,
          penalty='l2', random_state=None, solver='liblinear', tol=0.0001,
          verbose=0, warm_start=False)
F1 Score :  0.939383132895785
```

```
In [42]: """
         This code snippet deals with RandomizedSearchCV
         """
         parameters = { 'C' : uniform(10**-3,10**3)}
         f1_scorer = make_scorer(f1_score, pos_label="positive")
         model = RandomizedSearchCV(LogisticRegression(), parameters, scoring = f1_scorer, cv=5
         model.fit(train_avg_w2v, y_train)
         print(model.best_estimator_)
         print("F1 Score : ",model.score(train_avg_w2v, y_train))
```

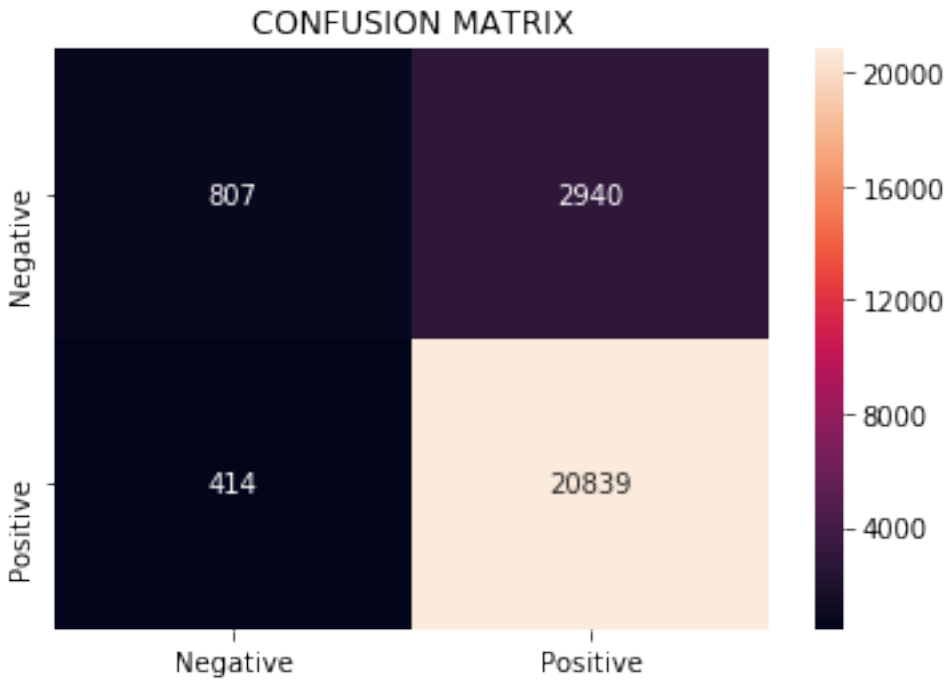
```
LogisticRegression(C=804.0099703308456, class_weight=None, dual=False,
          fit_intercept=True, intercept_scaling=1, max_iter=100,
          multi_class='ovr', n_jobs=1, penalty='l2', random_state=None,
          solver='liblinear', tol=0.0001, verbose=0, warm_start=False)
F1 Score :  0.939357149361095
```

```
In [43]: """
         In this code snippet finds sparsity and erorr using lamda from GridSearchCV.
         """
         clf = LogisticRegression(C=1, penalty='l2');
         clf.fit(train_avg_w2v, y_train);
         w = clf.coef_
         print("Sparsity : ",np.count_nonzero(w))
         # response prediction
         pred = clf.predict(test_avg_w2v)
```

```
        # evaluate error
        acc = accuracy_score(y_test, pred)*100
        print("Error : %.2f"%(100-acc))
        conf_matrix = confusion_matrix(y_test, pred)
        confusion_matrix_df = pd.DataFrame(conf_matrix,
                                           ["Negative", "Positive"],\
                                           ["Negative", "Positive"],\
                                           dtype=int)
        sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
        plt.title("CONFUSION MATRIX")
```

```
Sparsity :  50
Error : 13.42
```

Out[43]: Text(0.5,1,'CONFUSION MATRIX')

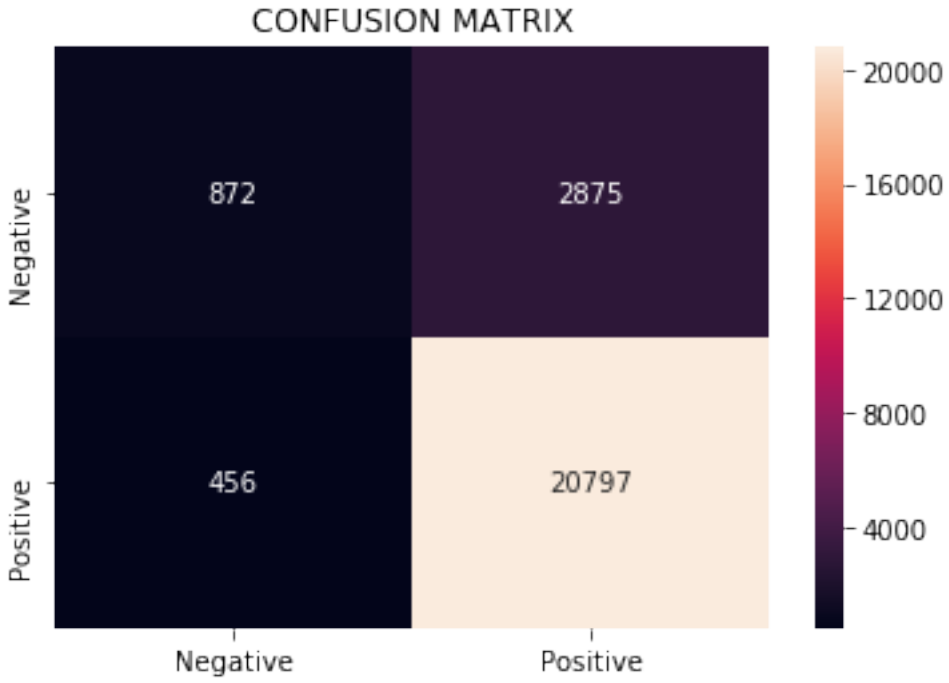


In [44]:
```
        """
        In this code snippet finds sparsity and erorr using lamda from GridSearchCV.
        """
        clf = LogisticRegression(C= 1, penalty='l1');
        clf.fit(train_avg_w2v, y_train);
        w = clf.coef_
        print("Sparsity : ",np.count_nonzero(w))
        # response prediction
```

```
        pred = clf.predict(test_avg_w2v)
        # evaluate error
        acc = accuracy_score(y_test, pred)*100
        print("Error : %.2f"%(100-acc))
        conf_matrix = confusion_matrix(y_test, pred)
        confusion_matrix_df = pd.DataFrame(conf_matrix,
                                           ["Negative", "Positive"],\
                                           ["Negative", "Positive"],\
                                           dtype=int)
        sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
        plt.title("CONFUSION MATRIX")
```

```
Sparsity :  50
Error : 13.32
```

Out[44]: Text(0.5,1,'CONFUSION MATRIX')

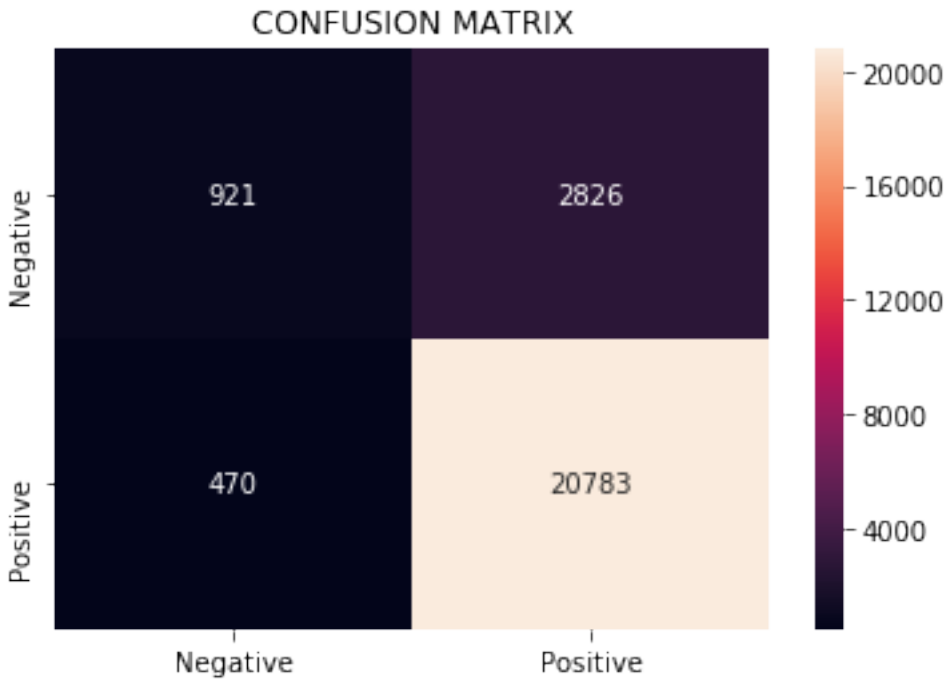


In [59]:
```
        """
        In this code snippet finds sparsity and erorr using lamda from RandomizedSearchCV.
        """
        clf = LogisticRegression(C=0.001, penalty='l2');
        clf.fit(train_avg_w2v, y_train);
        w = clf.coef_
        print("Sparsity : ",np.count_nonzero(w))
```

```
        # response prediction
        pred = clf.predict(test_avg_w2v)
        # evaluate error
        acc = accuracy_score(y_test, pred)*100
        print("Error : %.2f"%(100-acc))
        conf_matrix = confusion_matrix(y_test, pred)
        confusion_matrix_df = pd.DataFrame(conf_matrix,
                                           ["Negative", "Positive"],\
                                           ["Negative", "Positive"],\
                                           dtype=int)
        sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
        plt.title("CONFUSION MATRIX")
```

```
Sparsity :  50
Error : 13.18
```

Out[59]: Text(0.5,1,'CONFUSION MATRIX')



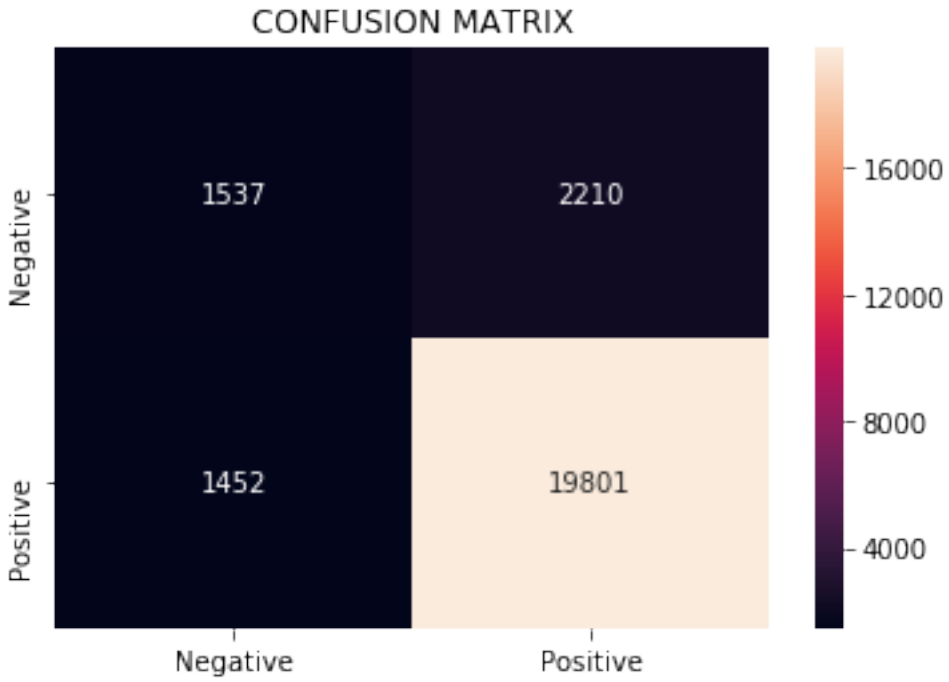

```
In [177]: """Lists to store lambda and error values"""
          lambda_list = [0.02,0.002,0.0002]
          train_error = []
          test_error = []
```

```
In [178]: """
          In this code snippet finds sparsity and erorr using lamda from RandomizedSearchCV.
```

```
"""
clf = LogisticRegression(C=0.001, penalty='l1');
clf.fit(train_avg_w2v, y_train);
w = clf.coef_
print("Sparsity : ",np.count_nonzero(w))
# response prediction
pred = clf.predict(test_avg_w2v)
# evaluate error
acc = accuracy_score(y_test, pred)*100
print("Error : %.2f"%(100-acc))
train_error.append(100-acc)
conf_matrix = confusion_matrix(y_test, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Sparsity :  25
Error : 14.65
```

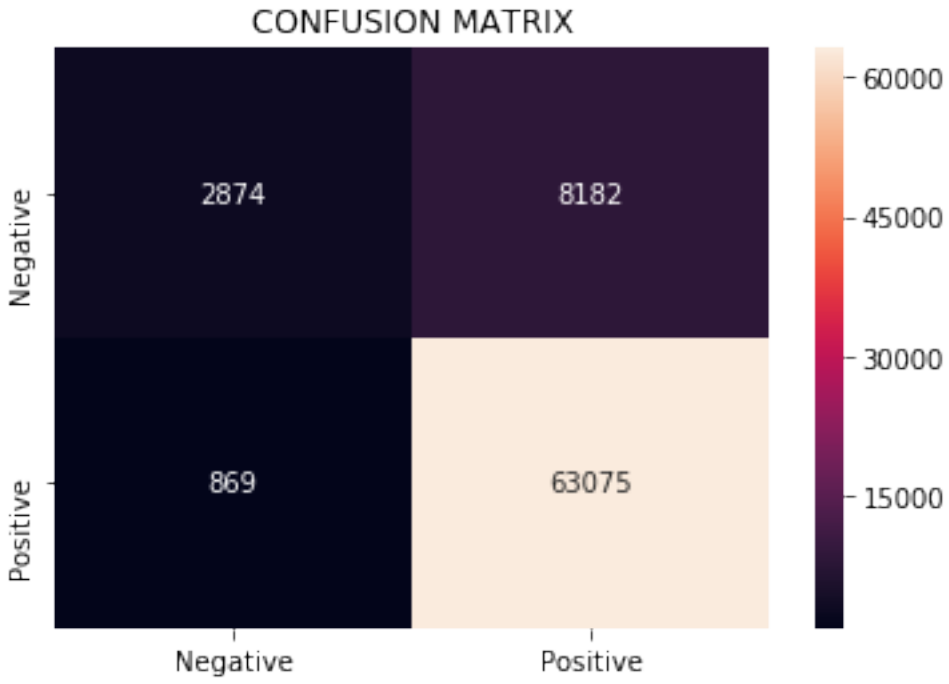
Out[178]: Text(0.5,1,'CONFUSION MATRIX')



In [179]:
```
"""
In this code snippet finds sparsity and train erorr using lamda value from Randomize
"""
# response prediction
pred = clf.predict(train_avg_w2v)
# evaluate error
acc = accuracy_score(y_train, pred)*100
print("Error : %.2f"%(100-acc))
test_error.append(100-acc)
conf_matrix = confusion_matrix(y_train, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Error : 12.07
```

Out[179]: Text(0.5,1,'CONFUSION MATRIX')

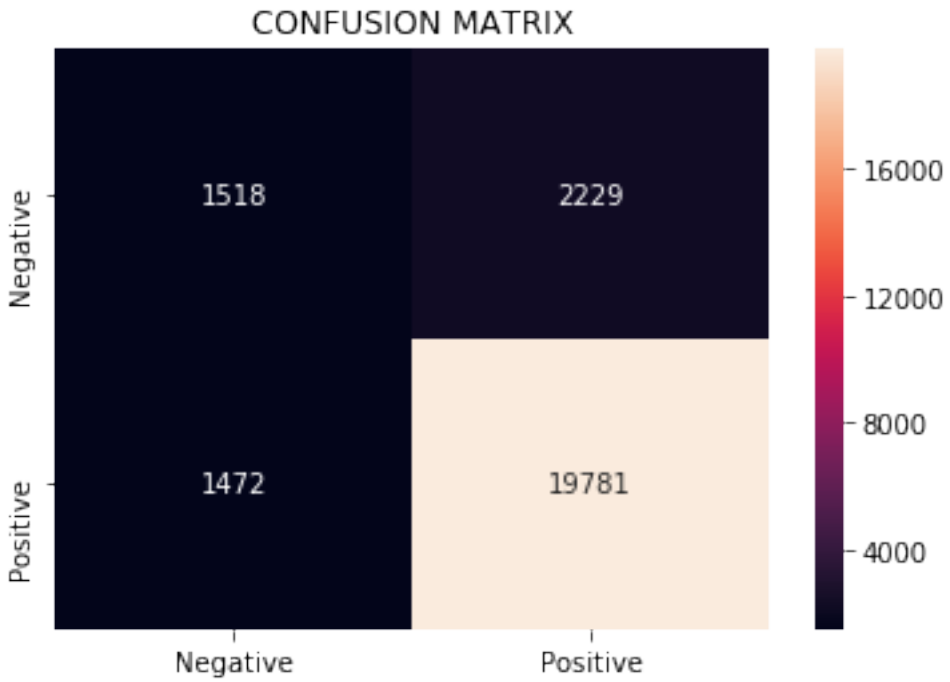


In [180]:
```
"""
In this code snippet finds sparsity and erorr using lamda from RandomizedSearchCV.
"""
```

```
            clf = LogisticRegression(C=0.0009, penalty='l1');
            clf.fit(train_avg_w2v, y_train);
            w = clf.coef_
            print("Sparsity : ",np.count_nonzero(w))
            # response prediction
            pred = clf.predict(test_avg_w2v)
            # evaluate error
            acc = accuracy_score(y_test, pred)*100
            print("Error : %.2f"%(100-acc))
            train_error.append(100-acc)
            conf_matrix = confusion_matrix(y_test, pred)
            confusion_matrix_df = pd.DataFrame(conf_matrix,
                                               ["Negative", "Positive"],\
                                               ["Negative", "Positive"],\
                                               dtype=int)
            sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
            plt.title("CONFUSION MATRIX")
```

```
Sparsity :  24
Error : 14.80
```

Out[180]: Text(0.5,1,'CONFUSION MATRIX')

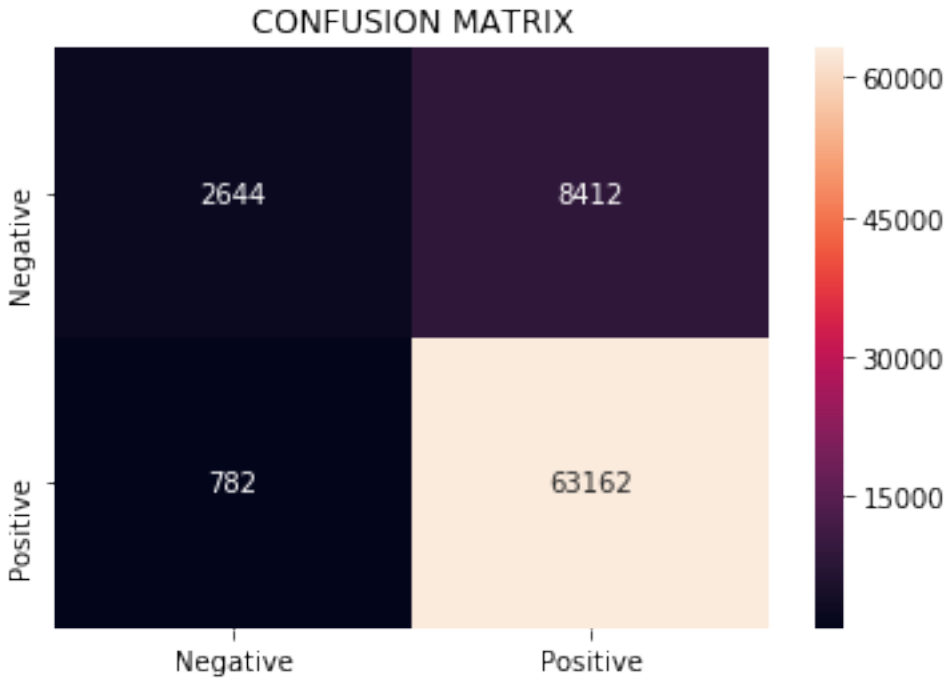


In [181]:
```
            """
            In this code snippet finds sparsity and train erorr using lamda value from Randomize
```

```
        """
        # response prediction
        pred = clf.predict(train_avg_w2v)
        # evaluate error
        acc = accuracy_score(y_train, pred)*100
        print("Error : %.2f"%(100-acc))
        test_error.append(100-acc)
        conf_matrix = confusion_matrix(y_train, pred)
        confusion_matrix_df = pd.DataFrame(conf_matrix,
                                           ["Negative", "Positive"],\
                                           ["Negative", "Positive"],\
                                           dtype=int)
        sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
        plt.title("CONFUSION MATRIX")
```

```
Error : 12.26
```

```
Out[181]: Text(0.5,1,'CONFUSION MATRIX')
```

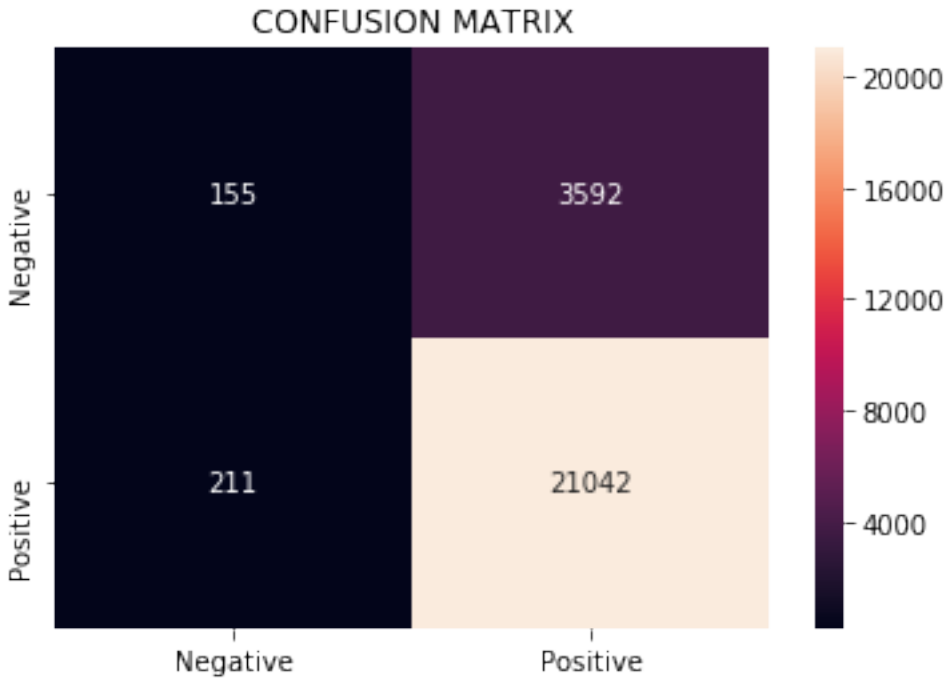



```
In [182]: """
          In this code snippet finds sparsity and erorr using lamda from RandomizedSearchCV.
          """
          clf = LogisticRegression(C=0.0001, penalty='l1');
          clf.fit(train_avg_w2v, y_train);
```

```
        w = clf.coef_
        print("Sparsity : ",np.count_nonzero(w))
        # response prediction
        pred = clf.predict(test_avg_w2v)
        # evaluate error
        acc = accuracy_score(y_test, pred)*100
        print("Error : %.2f"%(100-acc))
        train_error.append(100-acc)
        conf_matrix = confusion_matrix(y_test, pred)
        confusion_matrix_df = pd.DataFrame(conf_matrix,
                                           ["Negative", "Positive"],\
                                           ["Negative", "Positive"],\
                                           dtype=int)
        sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
        plt.title("CONFUSION MATRIX")
```

```
Sparsity :  5
Error : 15.21
```

Out[182]: Text(0.5,1,'CONFUSION MATRIX')

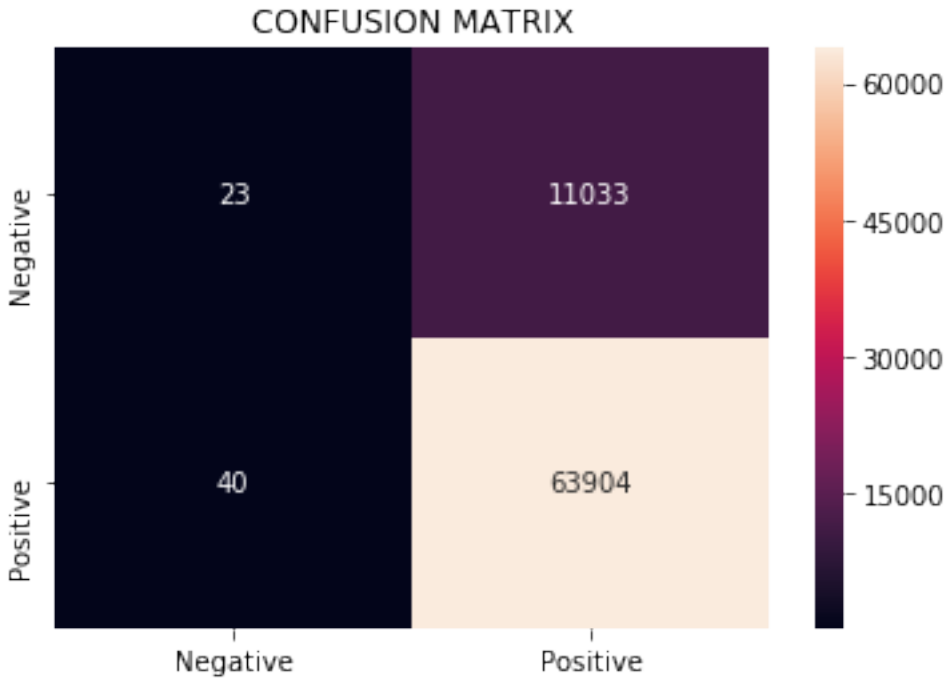


In [183]:
```
        """
        In this code snippet finds sparsity and train erorr using lamda value from Randomize
        """
```

```
        # response prediction
        pred = clf.predict(train_avg_w2v)
        # evaluate error
        acc = accuracy_score(y_train, pred)*100
        print("Error : %.2f"%(100-acc))
        test_error.append(100-acc)
        conf_matrix = confusion_matrix(y_train, pred)
        confusion_matrix_df = pd.DataFrame(conf_matrix,
                                           ["Negative", "Positive"],\
                                           ["Negative", "Positive"],\
                                           dtype=int)
        sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
        plt.title("CONFUSION MATRIX")
```

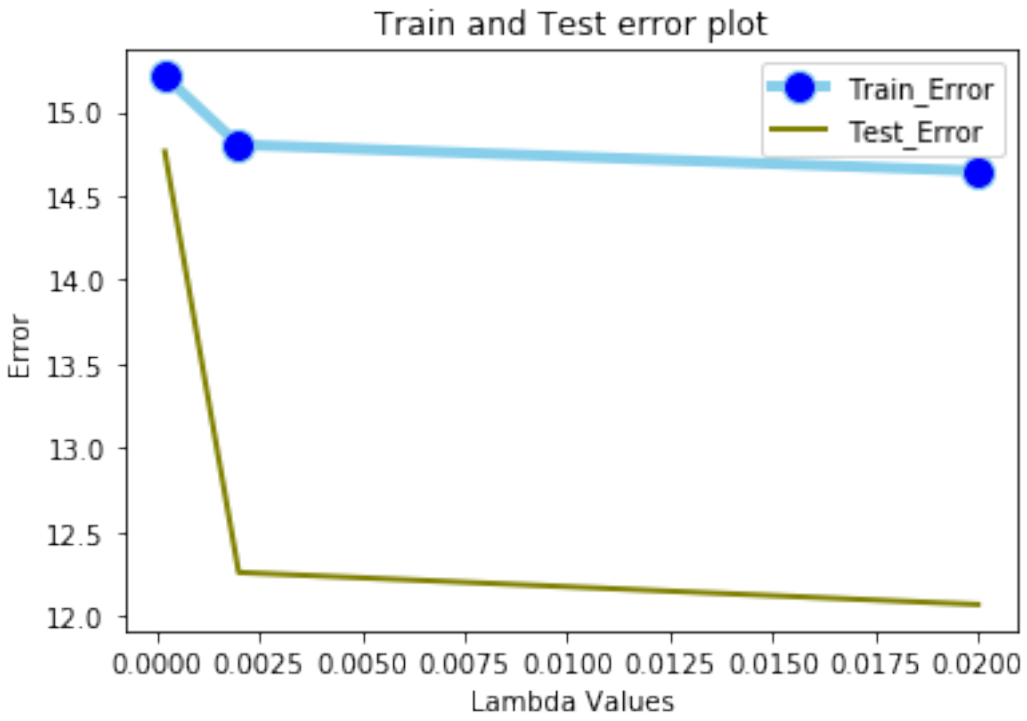
```
Error : 14.76
```

Out[183]: Text(0.5,1,'CONFUSION MATRIX')




```
In [184]: Train_Error, = plt.plot( lambda_list, train_error, marker='o',\
                                  markerfacecolor='blue', markersize=12,\
                                  color='skyblue', linewidth=4)
          Test_Error,  = plt.plot( lambda_list, test_error, marker='',\
                                  color='olive', linewidth=2)
          plt.xlabel('Lambda Values')
```

```
plt.ylabel('Error')
plt.title('Train and Test error plot')
plt.legend([Train_Error,Test_Error], ["Train_Error","Test_Error"])
plt.show()
```



In [64]:
```
"""
This code snippet shows effect of colinearity of on weight vectors
"""
x = copy.deepcopy(train_avg_w2v)

clf = LogisticRegression(C=0.001, penalty='l1');
clf.fit(train_avg_w2v, y_train);
w = clf.coef_
a = np.transpose(np.nonzero(w))
print("Weight vector before perturbation :", end=" ")
for i,j in a[:20]:
    print("%.5f"%w[i,j], end=" ")

print("\n")

# perturbation technique start
epsilon = np.random.normal(loc=0.0, scale=0.01)
a = np.transpose(np.nonzero(x))
for i,j in a:
```

```
            x[i,j] += epsilon
        # perturbation technique end

        clf = LogisticRegression(C=0.001 , penalty='l1');
        clf.fit(x, y_train);
        w = clf.coef_
        a = np.transpose(np.nonzero(w))
        print("Weight vector after perturbation :", end=" ")
        for i,j in a[:20]:
            print("%.5f"%w[i,j], end=" ")

        # deleting the variable to free RAM
        del x
```

```
Weight vector before perturbation : -0.18761 -0.35046 0.33493 0.11416 -0.08674 -0.11332 0.1114

Weight vector after perturbation : -0.19211 -0.35466 0.33445 0.11317 -0.08735 -0.11632 0.10879
```

```
In [63]: """
         This code snippet prints top 10 important features along with there index no
         """
         clf = LogisticRegression(C=0.001, penalty='l1');
         clf.fit(train_avg_w2v, y_train);
         w = clf.coef_
         a = [i for i in sorted(enumerate(w[0]),key=lambda pair: pair[1], reverse = True) if i
         print("FeatureIndex  FeatureWeight\n")
         print(*a[:10],sep = '\n')
```

```
FeatureIndex  FeatureWeight

(26, 0.743125442521408)
(37, 0.3602241152831083)
(8, 0.3348152640858897)
(29, 0.30070132251814846)
(19, 0.2590928922351227)
(43, 0.20244371107010584)
(34, 0.19416609132792062)
(20, 0.1604415531310982)
(18, 0.1410386353493387)
(45, 0.1342840935593244)
```

Observation:

- Here we have applied average word2vec to convert text to vector.
- We got hyperparameter(lambda) from GridSearchCV is 1 and from RandomizedSearchCV is 804 .
- I got best result from a model where C = 0.001, sparsity = 50 and the minimum error 13.18.
- In above models as we are reducing dimensions, so, weight vector and colinearity are not much helpful.

1.5.2 b) TF IDF Word2Vec

In [11]:
```
"""
This code snippet converts train data from text to vectors by TF-IDF weighted Word2Ve
"""
tf_idf_vect = TfidfVectorizer(ngram_range=(1,2), analyzer = 'word')
final_tf_idf = tf_idf_vect.fit_transform(x_train)
tfidf_feat = tf_idf_vect.get_feature_names() # tfidf words/col-names
# final_tf_idf is the sparse matrix with row= sentence, col=word and cell_val = tfidf
tfidf_train_vectors = []; # the tfidf-w2v for each sentence/review is stored in this
row=0;
for sent in list_of_train_sent: # 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
        try:
            vec = w2v_train_model.wv[word]
            # obtain the tf_idfidf of a word in a sentence/review
            tf_idf = final_tf_idf[row, tfidf_feat.index(word)]
            sent_vec += (vec * tf_idf)
            weight_sum += tf_idf
        except:
            pass
    if weight_sum == 0:
        weight_sum = 1
    sent_vec /= weight_sum
    tfidf_train_vectors.append(sent_vec)
    row += 1
train_tf_idf_w2v = np.asmatrix(tfidf_train_vectors)
```

In [12]:
```
"""
This code snippet converts test data from text to vectors by TF-IDF weighted Word2Vec
"""
final_tf_idf = tf_idf_vect.transform(x_test)
tfidf_feat = tf_idf_vect.get_feature_names() # tfidf words/col-names
# final_tf_idf is the sparse matrix with row= sentence, col=word and cell_val = tfidf
tfidf_test_vectors = []; # the tfidf-w2v for each sentence/review is stored in this l
row=0;
for sent in list_of_test_sent: # 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
        try:
            vec = w2v_test_model.wv[word]
            # obtain the tf_idfidf of a word in a sentence/review
            tf_idf = final_tf_idf[row, tfidf_feat.index(word)]
            sent_vec += (vec * tf_idf)
            weight_sum += tf_idf
        except:
```

```
                pass
            if weight_sum == 0:
                weight_sum = 1
            sent_vec /= weight_sum
            tfidf_test_vectors.append(sent_vec)
            row += 1
        test_tf_idf_w2v = np.asmatrix(tfidf_test_vectors)
```

In [13]:
```
"""
Standardize both training and test data
"""
scale = StandardScaler(with_mean = False)
train_tf_idf_w2v = scale.fit_transform(train_tf_idf_w2v)
test_tf_idf_w2v  = scale.transform(test_tf_idf_w2v)
print("Train data shape : ",train_tf_idf_w2v.shape)
print("Test data shape : ",test_tf_idf_w2v.shape)
```

```
Train data shape :  (75000, 50)
Test data shape :  (25000, 50)
```

In [14]:
```
import pickle
pickle_out = open("train_tf_idf_w2v.pkl", "wb")
pickle.dump(train_tf_idf_w2v, pickle_out)
pickle_out.close()
pickle_out = open("test_tf_idf_w2v.pkl", "wb")
pickle.dump(test_tf_idf_w2v, pickle_out)
pickle_out.close()
```

In [15]:
```
"""
This code snippet deals with GridSearchCV
"""
tuned_parameters = [{ 'C' : [10**-4, 10**-2, 10**0, 10**2, 10**4]}]
f1_scorer = make_scorer(f1_score, pos_label="positive")
model = GridSearchCV(LogisticRegression(), tuned_parameters, scoring = f1_scorer, cv=5
model.fit(train_tf_idf_w2v, y_train)
print(model.best_estimator_)
print("F1 Score : ",model.score(train_tf_idf_w2v, y_train))
```

```
LogisticRegression(C=100, class_weight=None, dual=False, fit_intercept=True,
          intercept_scaling=1, max_iter=100, multi_class='ovr', n_jobs=1,
          penalty='l2', random_state=None, solver='liblinear', tol=0.0001,
          verbose=0, warm_start=False)
F1 Score :  0.9326301693461628
```

In [16]:
```
"""
This code snippet deals with RandomizedSearchCV
"""
```

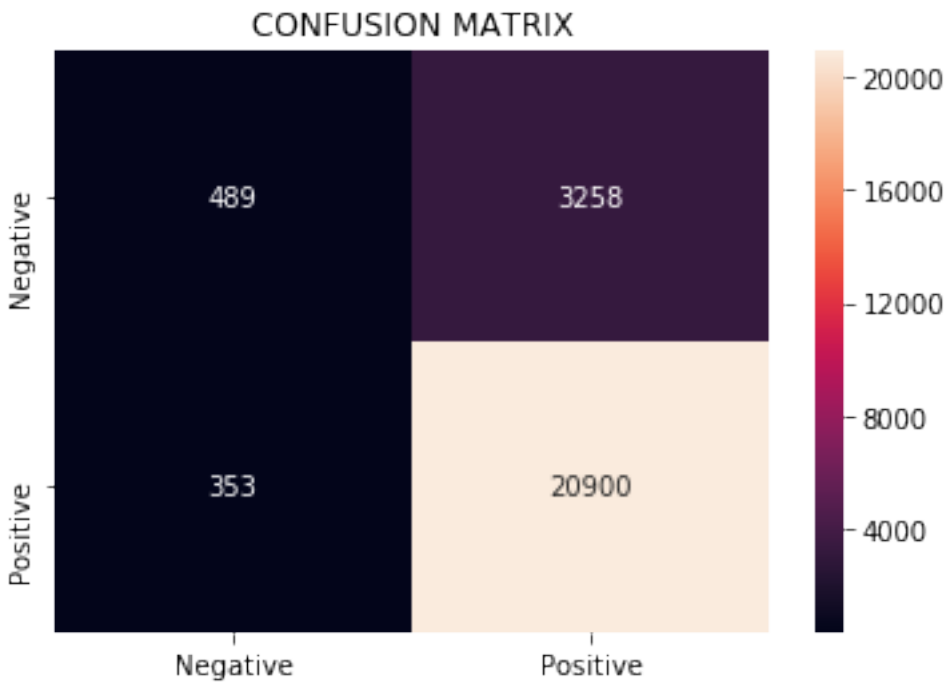
```
        parameters = { 'C' : uniform(10**-2,10**2)}
        f1_scorer = make_scorer(f1_score, pos_label="positive")
        model = RandomizedSearchCV(LogisticRegression(), parameters, scoring = f1_scorer, cv=5
        model.fit(train_tf_idf_w2v, y_train)
        print(model.best_estimator_)
        print("F1 Score : ",model.score(train_tf_idf_w2v, y_train))
```

```
LogisticRegression(C=96.38755692569153, class_weight=None, dual=False,
          fit_intercept=True, intercept_scaling=1, max_iter=100,
          multi_class='ovr', n_jobs=1, penalty='l2', random_state=None,
          solver='liblinear', tol=0.0001, verbose=0, warm_start=False)
F1 Score :  0.9326311829979312
```

In [45]:
```
        """
        In this code snippet finds sparsity and erorr using lamda from GridSearchCV.
        """
        clf = LogisticRegression(C=0.01, penalty='l2');
        clf.fit(train_tf_idf_w2v, y_train);
        w = clf.coef_
        print("Sparsity : ",np.count_nonzero(w))
        # response prediction
        pred = clf.predict(test_tf_idf_w2v)
        # evaluate error
        acc = accuracy_score(y_test, pred)*100
        print("Error : %.2f"%(100-acc))
        conf_matrix = confusion_matrix(y_test, pred)
        confusion_matrix_df = pd.DataFrame(conf_matrix,
                                           ["Negative", "Positive"],\
                                           ["Negative", "Positive"],\
                                           dtype=int)
        sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
        plt.title("CONFUSION MATRIX")
```

```
Sparsity :  50
Error : 14.44
```

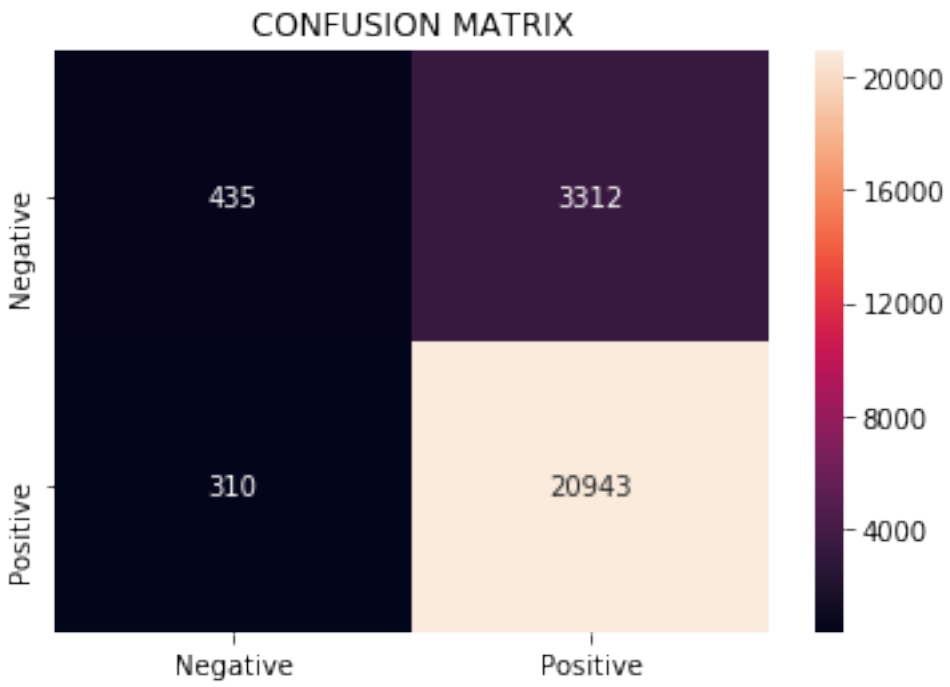
Out[45]:
```
Text(0.5,1,'CONFUSION MATRIX')
```



In [46]:
```
"""
In this code snippet finds sparsity and erorr using lamda from GridSearchCV.
"""
clf = LogisticRegression(C=0.01, penalty='l1');
clf.fit(train_tf_idf_w2v, y_train);
w = clf.coef_
print("Sparsity : ",np.count_nonzero(w))
# response prediction
pred = clf.predict(test_tf_idf_w2v)
# evaluate error
acc = accuracy_score(y_test, pred)*100
print("Error : %.2f"%(100-acc))
conf_matrix = confusion_matrix(y_test, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Sparsity :  46
Error : 14.49
```

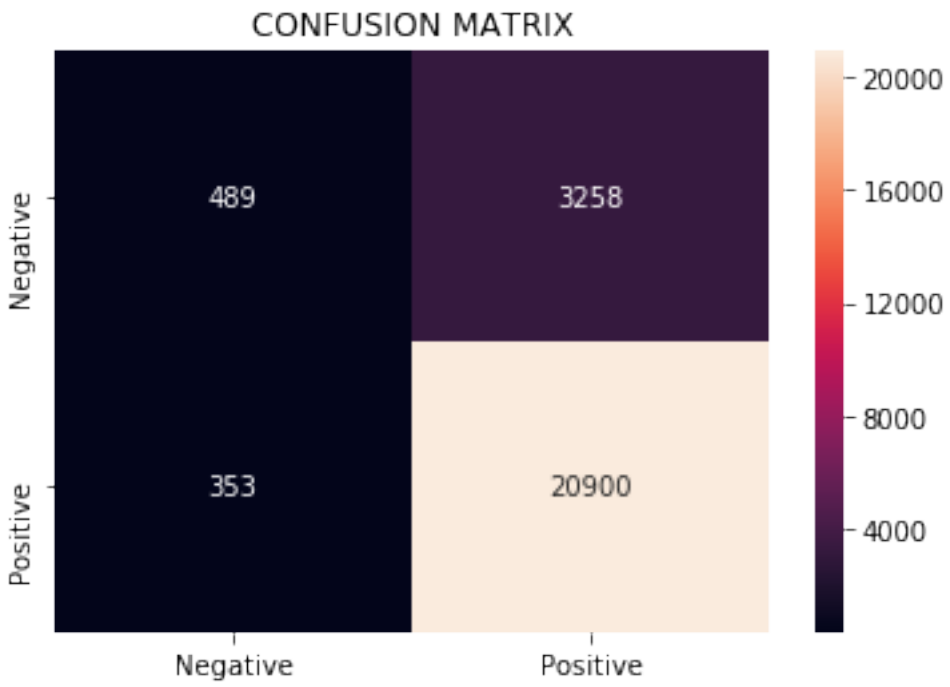
Out[46]: Text(0.5,1,'CONFUSION MATRIX')



In [66]:
```
"""
In this code snippet finds sparsity and erorr using lamda from RandomizedSearchCV.
"""
clf = LogisticRegression(C=0.01, penalty='l2');
clf.fit(train_tf_idf_w2v, y_train);
w = clf.coef_
print("Sparsity : ",np.count_nonzero(w))
# response prediction
pred = clf.predict(test_tf_idf_w2v)
# evaluate error
acc = accuracy_score(y_test, pred)*100
print("Error : %.2f"%(100-acc))
conf_matrix = confusion_matrix(y_test, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Sparsity :  50
Error : 14.44
```

Out[66]: Text(0.5,1,'CONFUSION MATRIX')

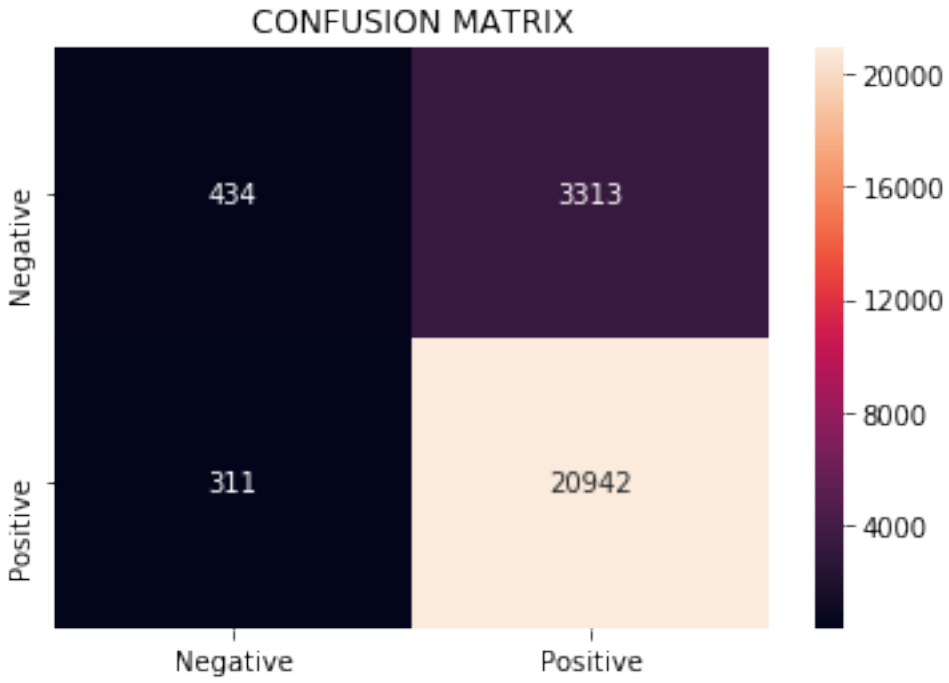


In [128]:
```
"""Lists to store lambda and error values"""
lambda_list = [0.02,0.002,0.0002]
train_error = []
test_error = []
```

In [129]:
```
"""
In this code snippet finds sparsity and erorr using lamda from RandomizedSearchCV.
"""
clf = LogisticRegression(C=0.01, penalty='l1');
clf.fit(train_tf_idf_w2v, y_train);
w = clf.coef_
print("Sparsity : ",np.count_nonzero(w))
# response prediction
pred = clf.predict(test_tf_idf_w2v)
# evaluate error
acc = accuracy_score(y_test, pred)*100
print("Error : %.2f"%(100-acc))
test_error.append(100-acc)
conf_matrix = confusion_matrix(y_test, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Sparsity :  46
Error : 14.50
```

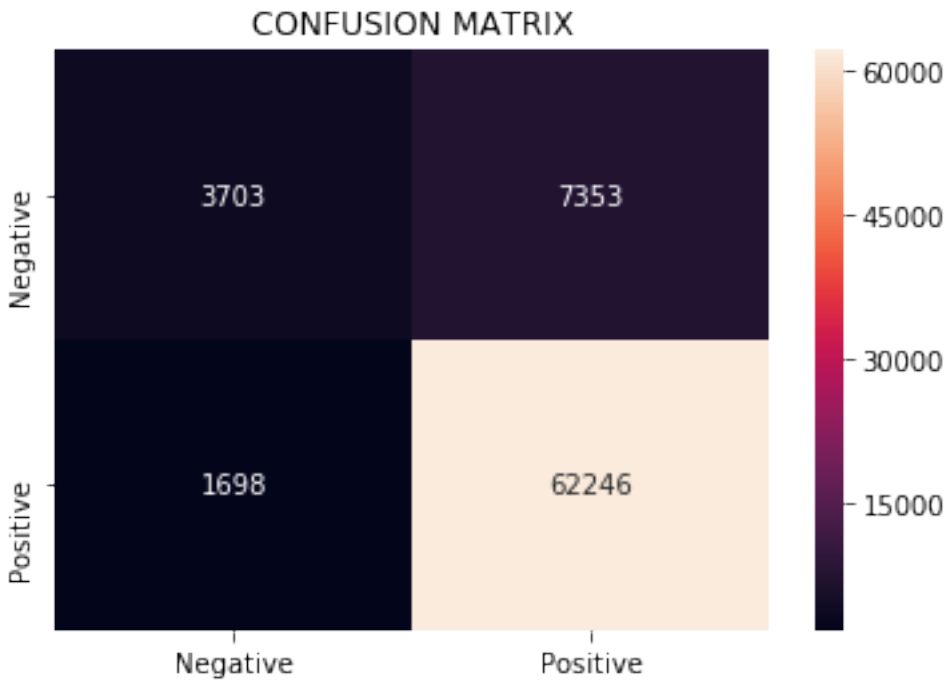
Out[129]: Text(0.5,1,'CONFUSION MATRIX')



In [130]:
```
"""
In this code snippet finds sparsity and train erorr using lamda value from Randomize
"""
# response prediction
pred = clf.predict(train_tf_idf_w2v)
# evaluate error
acc = accuracy_score(y_train, pred)*100
print("Error : %.2f"%(100-acc))
train_error.append(100-acc)
conf_matrix = confusion_matrix(y_train, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Error : 12.07
```

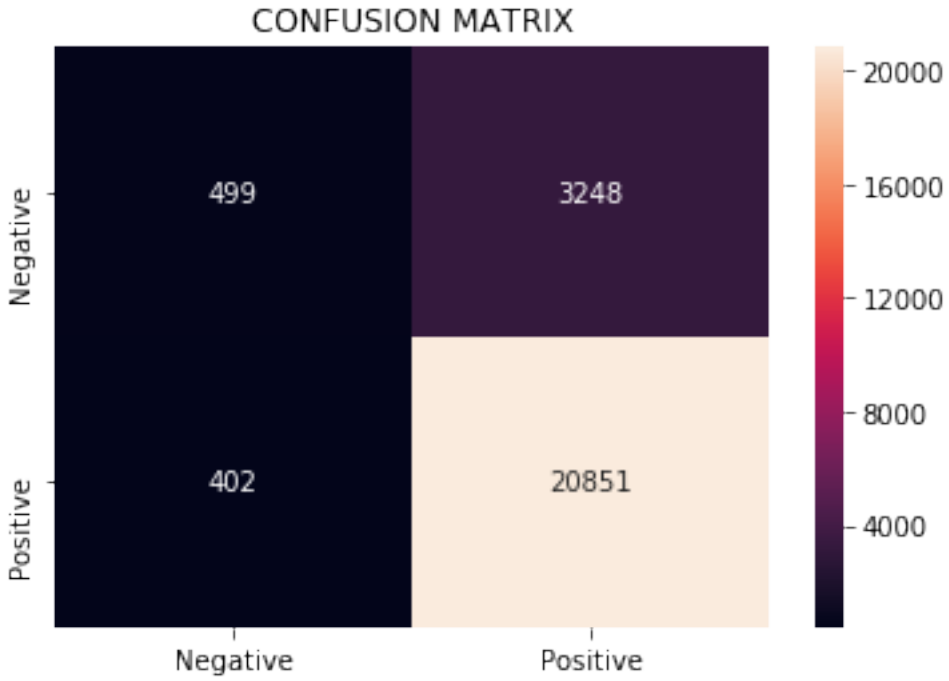
Out[130]: Text(0.5,1,'CONFUSION MATRIX')



In [131]:
```
"""
In this code snippet finds sparsity and erorr using lamda from RandomizedSearchCV.
"""
clf = LogisticRegression(C=0.001, penalty='l1');
clf.fit(train_tf_idf_w2v, y_train);
w = clf.coef_
print("Sparsity : ",np.count_nonzero(w))
# response prediction
pred = clf.predict(test_tf_idf_w2v)
# evaluate error
acc = accuracy_score(y_test, pred)*100
print("Error : %.2f"%(100-acc))
test_error.append(100-acc)
conf_matrix = confusion_matrix(y_test, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Sparsity :  23
Error : 14.60
```

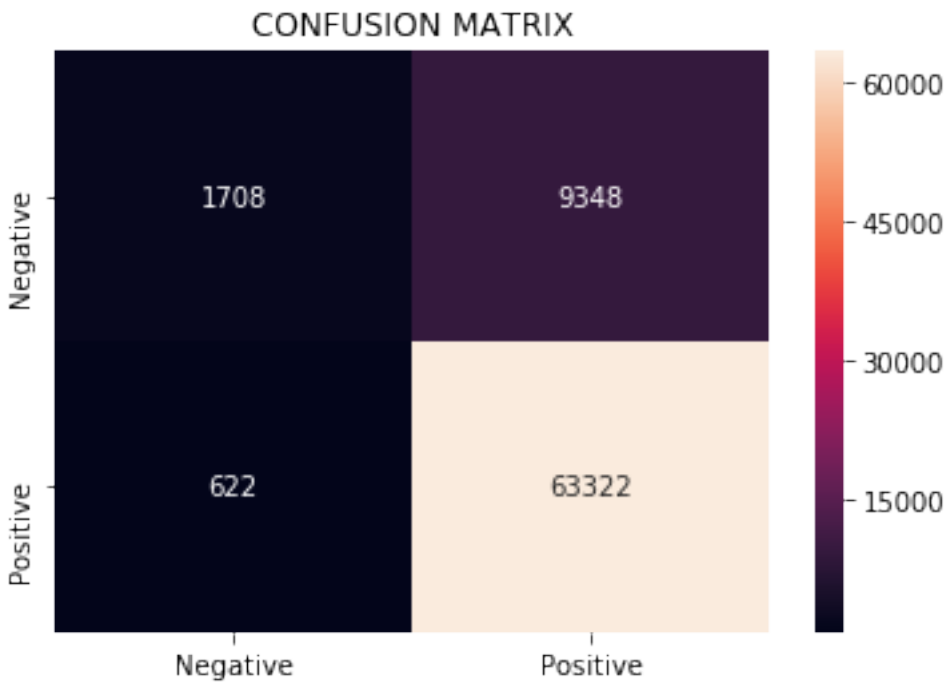
Out[131]: Text(0.5,1,'CONFUSION MATRIX')



In [132]:
```
"""
In this code snippet finds sparsity and train erorr using lamda value from Randomize
"""
# response prediction
pred = clf.predict(train_tf_idf_w2v)
# evaluate error
acc = accuracy_score(y_train, pred)*100
print("Error : %.2f"%(100-acc))
train_error.append(100-acc)
conf_matrix = confusion_matrix(y_train, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Error : 13.29
```

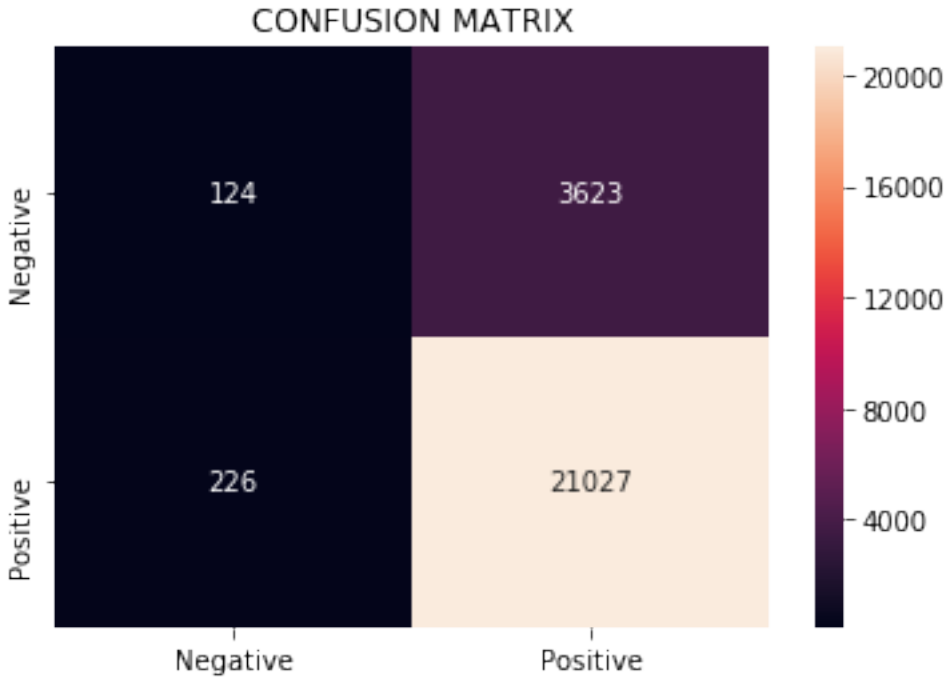
Out[132]: Text(0.5,1,'CONFUSION MATRIX')



In [133]:
```
"""
In this code snippet finds sparsity and erorr using lamda from RandomizedSearchCV.
"""
clf = LogisticRegression(C=0.0001, penalty='l1');
clf.fit(train_tf_idf_w2v, y_train);
w = clf.coef_
print("Sparsity : ",np.count_nonzero(w))
# response prediction
pred = clf.predict(test_tf_idf_w2v)
# evaluate error
acc = accuracy_score(y_test, pred)*100
print("Error : %.2f"%(100-acc))
test_error.append(100-acc)
conf_matrix = confusion_matrix(y_test, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Sparsity :  5
Error : 15.40
```

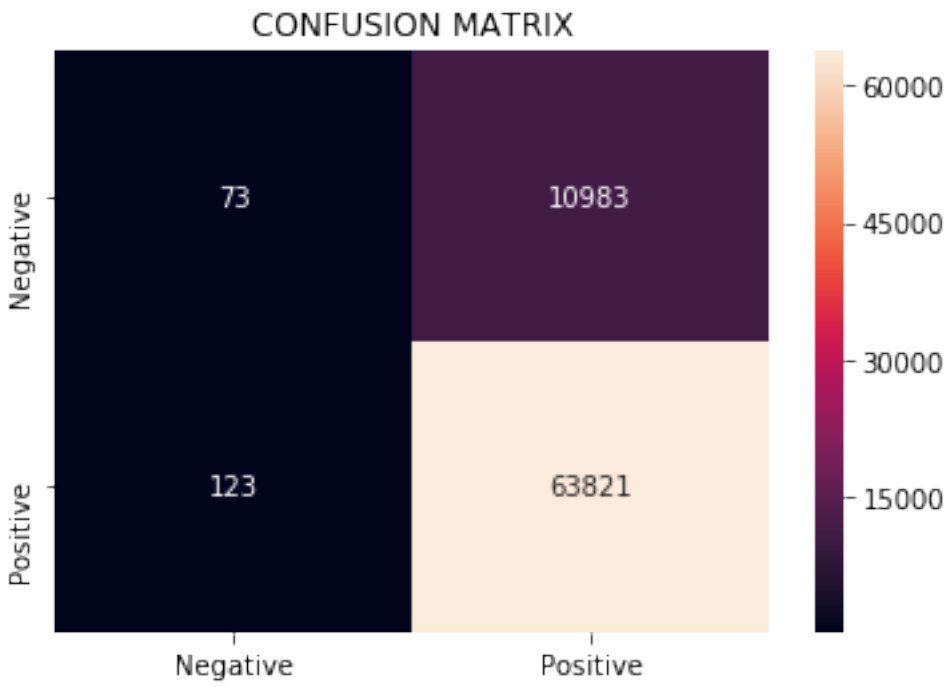
Out[133]: Text(0.5,1,'CONFUSION MATRIX')



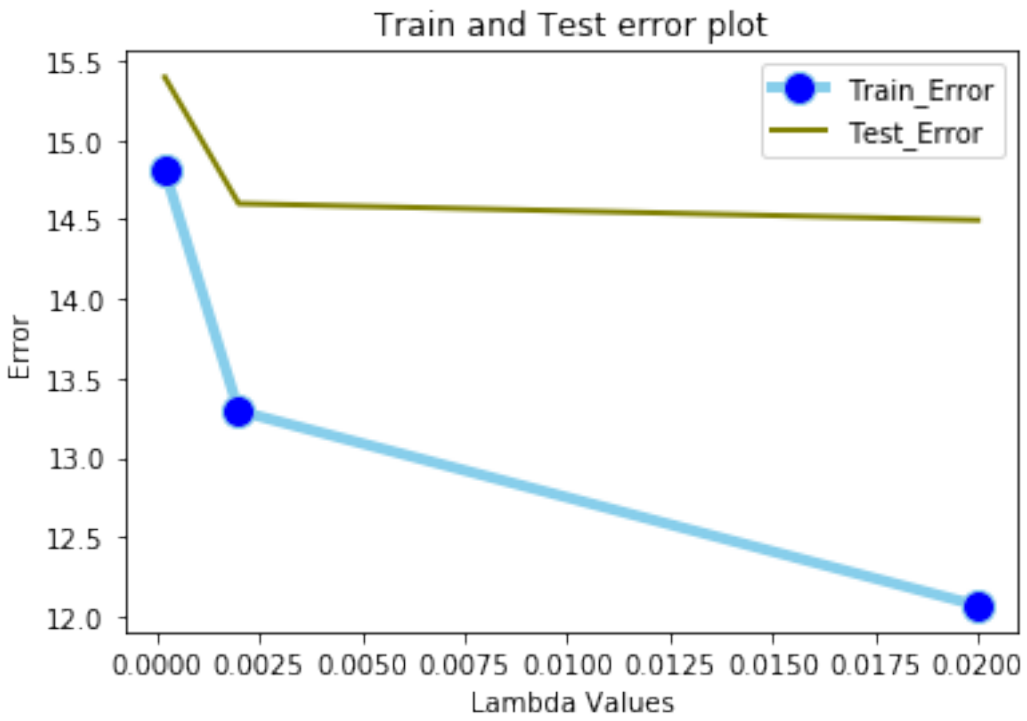
In [134]:
```
"""
In this code snippet finds sparsity and train erorr using lamda value from Randomize
"""
# response prediction
pred = clf.predict(train_tf_idf_w2v)
# evaluate error
acc = accuracy_score(y_train, pred)*100
print("Error : %.2f"%(100-acc))
train_error.append(100-acc)
conf_matrix = confusion_matrix(y_train, pred)
confusion_matrix_df = pd.DataFrame(conf_matrix,
                                   ["Negative", "Positive"],\
                                   ["Negative", "Positive"],\
                                   dtype=int)
sns.heatmap(confusion_matrix_df, annot=True, fmt="d")
plt.title("CONFUSION MATRIX")
```

```
Error : 14.81
```

Out[134]: Text(0.5,1,'CONFUSION MATRIX')




```
In [135]: Train_Error, = plt.plot( lambda_list, train_error, marker='o',\
                                  markerfacecolor='blue', markersize=12,\
                                  color='skyblue', linewidth=4)
          Test_Error,  = plt.plot( lambda_list, test_error, marker='',\
                                  color='olive', linewidth=2)
          plt.xlabel('Lambda Values')
          plt.ylabel('Error')
          plt.title('Train and Test error plot')
          plt.legend([Train_Error,Test_Error], ["Train_Error","Test_Error"])
          plt.show()
```



In [70]:
```
"""
This code snippet shows effect of colinearity of on weight vectors
"""
x = copy.deepcopy(train_tf_idf_w2v)

clf = LogisticRegression(C=0.01, penalty='l1');
clf.fit(train_tf_idf_w2v, y_train);
w = clf.coef_
a = np.transpose(np.nonzero(w))
print("Weight vector before perturbation :", end=" ")
for i,j in a[:20]:
    print("%.5f"%w[i,j], end=" ")

print("\n")

# perturbation technique start
epsilon = np.random.normal(loc=0.0, scale=0.01)
a = np.transpose(np.nonzero(x))
for i,j in a:
    x[i,j] += epsilon
# perturbation technique end

clf = LogisticRegression(C=0.01, penalty='l1');
clf.fit(x, y_train);
```

```
        w = clf.coef_
        a = np.transpose(np.nonzero(w))
        print("Weight vector after perturbation :", end=" ")
        for i,j in a[:20]:
            print("%.5f"%w[i,j], end=" ")

        # deleting the variable to free RAM
        del x
```

```
Weight vector before perturbation : 0.08694 -0.38302 0.22105 0.24121 -0.11721 0.17038 -0.42431

Weight vector after perturbation : 0.08488 -0.38228 0.22008 0.23916 -0.11353 0.17034 -0.42079
```

```
In [69]: """
         This code snippet prints top 10 important features along with there index no
         """
         clf = LogisticRegression(C=0.01, penalty='l1');
         clf.fit(train_tf_idf_w2v, y_train);
         w = clf.coef_
         a = [i for i in sorted(enumerate(w[0]),key=lambda pair: pair[1], reverse = True) if i
         print("FeatureIndex  FeatureWeight\n")
         print(*a[:10],sep = '\n')
```

```
FeatureIndex  FeatureWeight

(26, 0.8190866591633971)
(8, 0.6500719981139358)
(43, 0.49860403477019305)
(37, 0.4951671255900718)
(15, 0.48158254020543895)
(19, 0.4298810359667908)
(31, 0.3793480537526893)
(29, 0.3401697634786569)
(34, 0.34003910873861687)
(10, 0.33380820007262607)
```

Observation:

- Here we have applied TF IDF word2vec to convert text to vector.
- We got hyperparameter(lambda) from GridSearchCV is 100 and from RandomizedSearchCV is 96.38.
- I got best result from a model where C = 0.01, sparsity = 46 and the minimum error 14.50.
- In above models as we are reducing dimensions, so, weight vector and colinearity are not much helpful.

```
In [ ]: """
        This code snippet prepares a table that contains
        end results of diffrent models that we have used.
```

```
"""
table = PrettyTable()
table.field_names = ['Model','Best C','Regularizer','Lowest Error','Sparsity']
table.add_row(['BOW',0.02,'L1',8.31,6351])
table.add_row(['TF IDF',0.016,'L1',8.21,32487])
table.add_row(['AVG word2vec',0.001,'L2',13.48,50])
table.add_row(['TF IDF word2vec',0.01,'L1',14.50,46])
```

1.6 Conclusion :

1. From the above analysis with 100k sample of data I got that TF IDF is the best with less error 8.21% .
2. Colinearity is not affecting much to the features.
3. By applying TF_IDF vectorizer, we got a very less error and higher accuracy from Logistic Regression.
4. Until now Logistic Regression is the best classification technique that I have learned.
5. LR is labeling positive and negative points quite impressively with such a little and imbalanced dataset.

```
In [3]: print(table)
```

```
+-----------------+--------+-------------+--------------+----------+
|      Model      | Best C | Regularizer | Lowest Error | Sparsity |
+-----------------+--------+-------------+--------------+----------+
|       BOW       |  0.02  |      L1     |     8.31     |   6351   |
|      TF IDF     | 0.016  |      L1     |     8.21     |  32487   |
|   AVG word2vec  | 0.001  |      L2     |    13.48     |    50    |
| TF IDF word2vec |  0.01  |      L1     |     14.5     |    46    |
+-----------------+--------+-------------+--------------+----------+
```