In [1]:

```
import pandas as pd
import matplotlib.pyplot as plt
import re
import time
import warnings
import sqlite3
from sqlalchemy import create_engine # database connection
import csv
import os
warnings.filterwarnings("ignore")
import datetime as dt
import numpy as np
from nltk.corpus import stopwords
from sklearn.decomposition import TruncatedSVD
from sklearn.preprocessing import normalize
from sklearn.feature_extraction.text import CountVectorizer
from sklearn.manifold import TSNE
import seaborn as sns
from sklearn.neighbors import KNeighborsClassifier
from sklearn.metrics import confusion_matrix
from sklearn.metrics.classification import accuracy_score, log_loss
from sklearn.feature_extraction.text import TfidfVectorizer
from collections import Counter
from scipy.sparse import hstack
from sklearn.multiclass import OneVsRestClassifier
from sklearn.svm import SVC
from sklearn.model_selection import StratifiedKFold
from collections import Counter, defaultdict
from sklearn.calibration import CalibratedClassifierCV
from sklearn.naive_bayes import MultinomialNB
from sklearn.naive_bayes import GaussianNB
from sklearn.model_selection import train_test_split
from sklearn.model_selection import GridSearchCV
import math
from sklearn.metrics import normalized_mutual_info_score
from sklearn.ensemble import RandomForestClassifier



from sklearn.model_selection import cross_val_score
from sklearn.linear_model import SGDClassifier
from mlxtend.classifier import StackingClassifier

from sklearn import model_selection
from sklearn.linear_model import LogisticRegression
from sklearn.metrics import precision_recall_curve, auc, roc_curve
```

4. Machine Learning Models

4.1 Reading data from file and storing into sql table

In [5]:

```
#Creating db file from csv
if not os.path.isfile('train.db'):
    disk_engine = create_engine('sqlite:///train.db')
    start = dt.datetime.now()
    chunksize = 180000
    j = 0
    index_start = 1
    for df in pd.read_csv('final_features.csv', names=['Unnamed: 0','id','is_duplicate','cwc_min','
cwc_max','csc_min','csc_max','ctc_min','ctc_max','last_word_eq','first_word_eq','abs_len_diff','me
an_len','token_set_ratio','token_sort_ratio','fuzz_ratio','fuzz_partial_ratio','longest_substr_rati
o','freq_qid1','freq_qid2','q1len','q2len','q1_n_words','q2_n_words','word_Common','word_Total','w
ord_share','freq_q1+q2','freq_q1-
q2','0_x','1_x','2_x','3_x','4_x','5_x','6_x','7_x','8_x','9_x','10_x','11_x','12_x','13_x','14_x',
'15_x','16_x','17_x','18_x','19_x','20_x','21_x','22_x','23_x','24_x','25_x','26_x','27_x','28_x','
29_x','30_x','31_x','32_x','33_x','34_x','35_x','36_x','37_x','38_x','39_x','40_x','41_x','42_x','4
```

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3_x','44_x','45_x','46_x','47_x','48_x','49_x','50_x','51_x','52_x','53_x','54_x','55_x','56_x','57
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','86_x','87_x','88_x','89_x','90_x','91_x','92_x','93_x','94_x','95_x','96_x','97_x','98_x','99_x'
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3_x','174_x','175_x','176_x','177_x','178_x','179_x','180_x','181_x','182_x','183_x','184_x','185_
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9_x','370_x','371_x','372_x','373_x','374_x','375_x','376_x','377_x','378_x','379_x','380_x','381_
x','382_x','383_x','0_y','1_y','2_y','3_y','4_y','5_y','6_y','7_y','8_y','9_y','10_y','11_y','12_y'
,'13_y','14_y','15_y','16_y','17_y','18_y','19_y','20_y','21_y','22_y','23_y','24_y','25_y','26_y',
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41_y','42_y','43_y','44_y','45_y','46_y','47_y','48_y','49_y','50_y','51_y','52_y','53_y','54_y','5
5_y','56_y','57_y','58_y','59_y','60_y','61_y','62_y','63_y','64_y','65_y','66_y','67_y','68_y','69
_y','70_y','71_y','72_y','73_y','74_y','75_y','76_y','77_y','78_y','79_y','80_y','81_y','82_y','83_
y','84_y','85_y','86_y','87_y','88_y','89_y','90_y','91_y','92_y','93_y','94_y','95_y','96_y','97_y
','98_y','99_y','100_y','101_y','102_y','103_y','104_y','105_y','106_y','107_y','108_y','109_y','11
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147_y','148_y','149_y','150_y','151_y','152_y','153_y','154_y','155_y','156_y','157_y','158_y','15
9_y','160_y','161_y','162_y','163_y','164_y','165_y','166_y','167_y','168_y','169_y','170_y','171_
y','172_y','173_y','174_y','175_y','176_y','177_y','178_y','179_y','180_y','181_y','182_y','183_y'
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196_y','197_y','198_y','199_y','200_y','201_y','202_y','203_y','204_y','205_y','206_y','207_y','20
8_y','209_y','210_y','211_y','212_y','213_y','214_y','215_y','216_y','217_y','218_y','219_y','220_
y','221_y','222_y','223_y','224_y','225_y','226_y','227_y','228_y','229_y','230_y','231_y','232_y'
,'233_y','234_y','235_y','236_y','237_y','238_y','239_y','240_y','241_y','242_y','243_y','244_y','
245_y','246_y','247_y','248_y','249_y','250_y','251_y','252_y','253_y','254_y','255_y','256_y','25
7_y','258_y','259_y','260_y','261_y','262_y','263_y','264_y','265_y','266_y','267_y','268_y','269_
y','270_y','271_y','272_y','273_y','274_y','275_y','276_y','277_y','278_y','279_y','280_y','281_y'
,'282_y','283_y','284_y','285_y','286_y','287_y','288_y','289_y','290_y','291_y','292_y','293_y','
294_y','295_y','296_y','297_y','298_y','299_y','300_y','301_y','302_y','303_y','304_y','305_y','30
6_y','307_y','308_y','309_y','310_y','311_y','312_y','313_y','314_y','315_y','316_y','317_y','318_
y','319_y','320_y','321_y','322_y','323_y','324_y','325_y','326_y','327_y','328_y','329_y','330_y'
,'331_y','332_y','333_y','334_y','335_y','336_y','337_y','338_y','339_y','340_y','341_y','342_y','
343_y','344_y','345_y','346_y','347_y','348_y','349_y','350_y','351_y','352_y','353_y','354_y','35
5_y','356_y','357_y','358_y','359_y','360_y','361_y','362_y','363_y','364_y','365_y','366_y','367_
y','368_y','369_y','370_y','371_y','372_y','373_y','374_y','375_y','376_y','377_y','378_y','379_y'
,'380_y','381_y','382_y','383_y'], chunksize=chunksize, iterator=True, encoding='utf-8', ):
        df.index += index_start
        j+=1
        print('{} rows'.format(j*chunksize))
        df.to_sql('data', disk_engine, if_exists='append')
        index_start = df.index[-1] + 1
```

```
180000 rows
360000 rows
540000 rows
```

In [6]:

```
#http://www.sqlitetutorial.net/sqlite-python/create-tables/
def create_connection(db_file):
    """ create a database connection to the SQLite database
        specified by db_file
    :param db_file: database file
```

```
    :return: Connection object or None
    """
    try:
        conn = sqlite3.connect(db_file)
        return conn
    except Error as e:
        print(e)

    return None


def checkTableExists(dbcon):
    cursr = dbcon.cursor()
    str = "select name from sqlite_master where type='table'"
    table_names = cursr.execute(str)
    print("Tables in the databse:")
    tables =table_names.fetchall()
    print(tables[0][0])
    return(len(tables))
```

In [7]:

```
read_db = 'train.db'
conn_r = create_connection(read_db)
checkTableExists(conn_r)
conn_r.close()
```

```
Tables in the databse:
data
```

In [8]:

```
# try to sample data according to the computing power you have
if os.path.isfile(read_db):
    conn_r = create_connection(read_db)
    if conn_r is not None:
        # for selecting first 1M rows
        # data = pd.read_sql_query("""SELECT * FROM data LIMIT 100001;""", conn_r)

        # for selecting random points
        data = pd.read_sql_query("SELECT * From data ORDER BY RANDOM() LIMIT 100001;", conn_r)
        conn_r.commit()
        conn_r.close()
```

In [9]:

```
# remove the first row
data.drop(data.index[0], inplace=True)
y_true = data['is_duplicate']
data.drop(['Unnamed: 0', 'id','index','is_duplicate'], axis=1, inplace=True)
```

In [10]:

```
data.head()
```

Out[10]:

	cwc_min	cwc_max	csc_min	csc_max	ctc_min	ctc_max	last_word_eq
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.444439506227709	0.333330555578704	0.999980000399992	0.384612426058261	0.642852551053207	0.321427423473488	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.799984000319994	0.799984000319994	0.799984000319994	0.666655555740738	0.799992000079999	0.727266115762584	0.0
5	0.0	0.0	0.666644444518516	0.333327777870369	0.142856122456268	0.13333244445037	0.0

5 rows × 794 columns

4.2 Converting strings to numerics

In [11]:

```
# after we read from sql table each entry was read it as a string
# we convert all the features into numaric before we apply any model
cols = list(data.columns)
for i in cols:
    data[i] = data[i].apply(pd.to_numeric)
    print(i)
```

```
cwc_min
cwc_max
csc_min
csc_max
ctc_min
ctc_max
last_word_eq
first_word_eq
abs_len_diff
mean_len
token_set_ratio
token_sort_ratio
fuzz_ratio
fuzz_partial_ratio
longest_substr_ratio
freq_qid1
freq_qid2
q1len
q2len
q1_n_words
q2_n_words
word_Common
word_Total
word_share
freq_q1+q2
freq_q1-q2
0_x
1_x
2_x
3_x
4_x
5_x
6_x
7_x
8_x
9_x
10_x
11_x
12_x
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```

In [0]:

```
# https://stackoverflow.com/questions/7368789/convert-all-strings-in-a-list-to-int
y_true = list(map(int, y_true.values))
```

4.3 Random train test split(70:30)

In [12]:

```
X_train,X_test, y_train, y_test = train_test_split(data, y_true, stratify=y_true, test_size=0.3)
```

In [15]:

```
print("Number of data points in train data :",X_train.shape)
print("Number of data points in test data :",X_test.shape)
```

```
Number of data points in train data : (70000, 794)
Number of data points in test data : (30000, 794)
```

In [17]:

```
print(y_train.shape)
print(y_test.shape)
```

```
(70000,)
(30000,)
```

In [29]:

```
print("-"*10, "Distribution of output variable in train data", "-"*10)
train_distr = Counter(y_train)
train_len = len(y_train)
print("Class 0: ",int(train_distr['0'])/train_len,"Class 1: ", int(train_distr['1'])/train_len)
print("-"*10, "Distribution of output variable in test data", "-"*10)
test_distr = Counter(y_test)
test_len = len(y_test)
print("Class 0: ",int(test_distr['1'])/test_len, "Class 1: ",int(test_distr['1'])/test_len)
```

```
---------- Distribution of output variable in train data ----------
Class 0:  0.6306428571428572 Class 1:  0.3693571428571429
---------- Distribution of output variable in test data ----------
Class 0:  0.36933333333333335 Class 1:  0.36933333333333335
```

In [2]:

```
# This function plots the confusion matrices given y_i, y_i_hat.
def plot_confusion_matrix(test_y, predict_y):
    C = confusion_matrix(test_y, predict_y)
    # C = 9,9 matrix, each cell (i,j) represents number of points of class i are predicted class j

    A =(((C.T)/(C.sum(axis=1))).T)
    #divid each element of the confusion matrix with the sum of elements in that column

    # C = [[1, 2],
    #     [3, 4]]
    # C.T = [[1, 3],
    #        [2, 4]]
    # C.sum(axis = 1)  axis=0 corresonds to columns and axis=1 corresponds to rows in two
diamensional array
    # C.sum(axix =1) = [[3, 7]]
    # ((C.T)/(C.sum(axis=1))) = [[1/3, 3/7]
    #                            [2/3, 4/7]]

    # ((C.T)/(C.sum(axis=1))).T = [[1/3, 2/3]
    #                            [3/7, 4/7]]
    # sum of row elements = 1

    B =(C/C.sum(axis=0))
    #divid each element of the confusion matrix with the sum of elements in that row
    # C = [[1, 2],
    #     [3, 4]]
    # C.sum(axis = 0)  axis=0 corresonds to columns and axis=1 corresponds to rows in two
diamensional array
    # C.sum(axix =0) = [[4, 6]]
    # (C/C.sum(axis=0)) = [[1/4, 2/6],
    #                       [3/4, 4/6]]
    plt.figure(figsize=(20,4))

    labels = [1,2]
    # representing A in heatmap format
    cmap=sns.light_palette("blue")
    plt.subplot(1, 3, 1)
    sns.heatmap(C, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, yticklabels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.title("Confusion matrix")

    plt.subplot(1, 3, 2)
    sns.heatmap(B, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, yticklabels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.title("Precision matrix")

    plt.subplot(1, 3, 3)
    # representing B in heatmap format
    sns.heatmap(A, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, yticklabels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.title("Recall matrix")

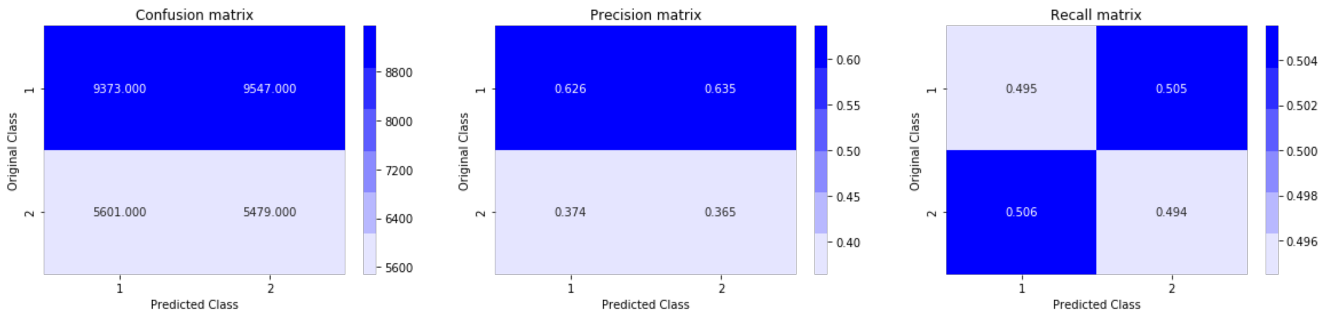
    plt.show()
```

4.4 Building a random model (Finding worst-case log-loss)

In [112]:

```
# we need to generate 9 numbers and the sum of numbers should be 1
# one solution is to genarate 9 numbers and divide each of the numbers by their sum
# ref: https://stackoverflow.com/a/18662466/4084039
# we create a output array that has exactly same size as the CV data
predicted_y = np.zeros((test_len,2))
for i in range(test_len):
    rand_probs = np.random.rand(1,2)
    predicted_y[i] = ((rand_probs/sum(sum(rand_probs)))[0])
print("Log loss on Test Data using Random Model",log_loss(y_test, predicted_y, eps=1e-15))
predicted_y =np.argmax(predicted_y, axis=1)
plot_confusion_matrix(y_test, predicted_y)
```

```
Log loss on Test Data using Random Model 0.8939451125217412
```



4.4 Logistic Regression with hyperparameter tuning

In [113]:

```
alpha = [10 ** x for x in range(-5, 2)] # hyperparam for SGD classifier.

# read more about SGDClassifier() at http://scikit-
learn.org/stable/modules/generated/sklearn.linear_model.SGDClassifier.html
# ------------------------------
# default parameters
# SGDClassifier(loss='hinge', penalty='l2', alpha=0.0001, l1_ratio=0.15, fit_intercept=True, max_i
ter=None, tol=None,
# shuffle=True, verbose=0, epsilon=0.1, n_jobs=1, random_state=None, learning_rate='optimal', eta0
=0.0, power_t=0.5,
# class_weight=None, warm_start=False, average=False, n_iter=None)

# some of methods
# fit(X, y[, coef_init, intercept_init, …]) Fit linear model with Stochastic Gradient Descent.
# predict(X) Predict class labels for samples in X.

#-------------------------------
# video link:
#------------------------------


log_error_array=[]
for i in alpha:
    clf = SGDClassifier(alpha=i, penalty='l2', loss='log', random_state=42)
    clf.fit(X_train, y_train)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(X_train, y_train)
    predict_y = sig_clf.predict_proba(X_test)
    log_error_array.append(log_loss(y_test, predict_y, labels=clf.classes_, eps=1e-15))
    print('For values of alpha = ', i, "The log loss is:",log_loss(y_test, predict_y, labels=clf.cl
asses_, eps=1e-15))

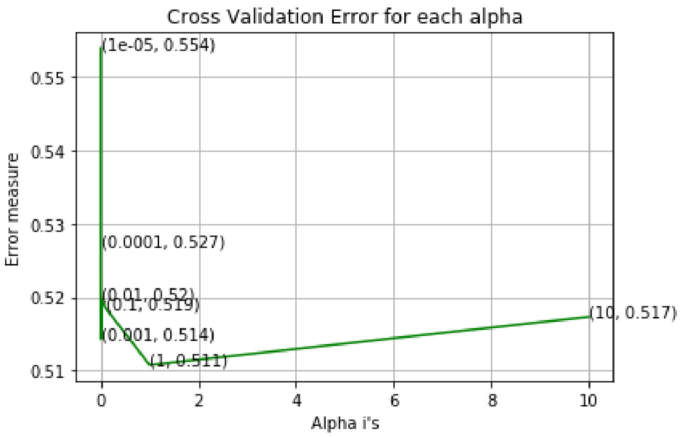
fig, ax = plt.subplots()
ax.plot(alpha, log_error_array,c='g')
for i, txt in enumerate(np.round(log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
```

```
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show()

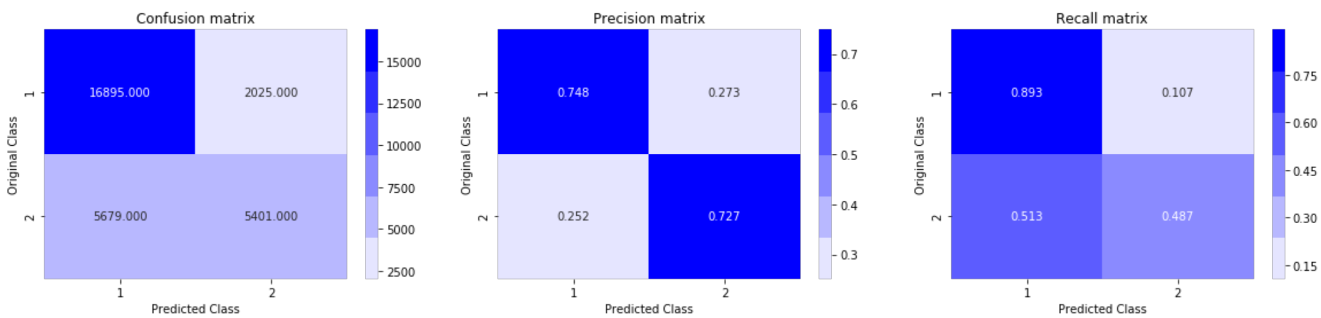

best_alpha = np.argmin(log_error_array)
clf = SGDClassifier(alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
clf.fit(X_train, y_train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_train, y_train)

predict_y = sig_clf.predict_proba(X_train)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(y_train, predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(X_test)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_test, predict_y, labels=clf.classes_, eps=1e-15))
predicted_y =np.argmax(predict_y,axis=1)
print("Total number of data points :", len(predicted_y))
plot_confusion_matrix(y_test, predicted_y)
```

```
For values of alpha =  1e-05 The log loss is: 0.553916879962817
For values of alpha =  0.0001 The log loss is: 0.5270208292426586
For values of alpha =  0.001 The log loss is: 0.5142780604558892
For values of alpha =  0.01 The log loss is: 0.519823433187696
For values of alpha =  0.1 The log loss is: 0.5185030323881291
For values of alpha =  1 The log loss is: 0.5107604016480848
For values of alpha =  10 The log loss is: 0.517296530116165
```




```
For values of best alpha =  1 The train log loss is: 0.505736582097431
For values of best alpha =  1 The test log loss is: 0.5107604016480848
Total number of data points : 30000
```



4.5 Linear SVM with hyperparameter tuning

In [114]:

```
alpha = [10 ** x for x in range(-5, 2)] # hyperparam for SGD classifier.

# read more about SGDClassifier() at http://scikit-learn.org/stable/modules/generated/sklearn.linear_model.SGDClassifier.html
# ------------------------------
# default parameters
```

```
# SGDClassifier(loss='hinge', penalty='l2', alpha=0.0001, l1_ratio=0.15, fit_intercept=True, max_i
ter=None, tol=None,
# shuffle=True, verbose=0, epsilon=0.1, n_jobs=1, random_state=None, learning_rate='optimal', eta0
=0.0, power_t=0.5,
# class_weight=None, warm_start=False, average=False, n_iter=None)

# some of methods
# fit(X, y[, coef_init, intercept_init, …]) Fit linear model with Stochastic Gradient Descent.
# predict(X) Predict class labels for samples in X.

#-------------------------------
# video link:
#-------------------------------

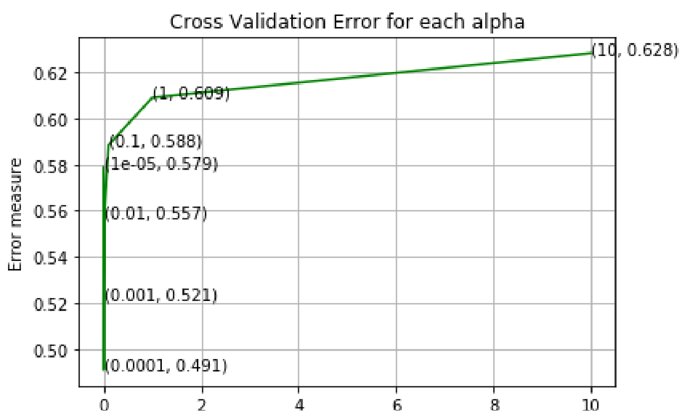

log_error_array=[]
for i in alpha:
    clf = SGDClassifier(alpha=i, penalty='l1', loss='hinge', random_state=42)
    clf.fit(X_train, y_train)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(X_train, y_train)
    predict_y = sig_clf.predict_proba(X_test)
    log_error_array.append(log_loss(y_test, predict_y, labels=clf.classes_, eps=1e-15))
    print('For values of alpha = ', i, "The log loss is:",log_loss(y_test, predict_y, labels=clf.cl
asses_, eps=1e-15))

fig, ax = plt.subplots()
ax.plot(alpha, log_error_array,c='g')
for i, txt in enumerate(np.round(log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show()


best_alpha = np.argmin(log_error_array)
clf = SGDClassifier(alpha=alpha[best_alpha], penalty='l1', loss='hinge', random_state=42)
clf.fit(X_train, y_train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(X_train, y_train)

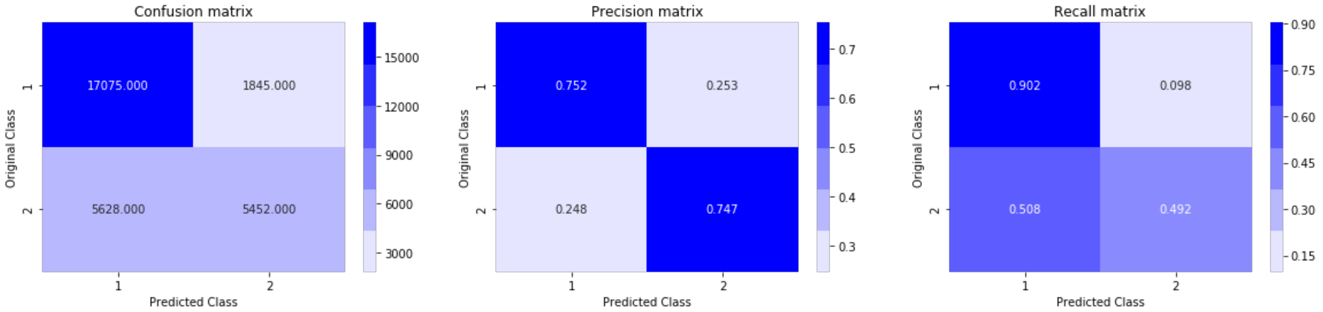
predict_y = sig_clf.predict_proba(X_train)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(y_train,
predict_y, labels=clf.classes_, eps=1e-15))
predict_y = sig_clf.predict_proba(X_test)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_test, p
redict_y, labels=clf.classes_, eps=1e-15))
predicted_y =np.argmax(predict_y,axis=1)
print("Total number of data points :", len(predicted_y))
plot_confusion_matrix(y_test, predicted_y)
```

```
For values of alpha =  1e-05 The log loss is: 0.5788774789903178
For values of alpha =  0.0001 The log loss is: 0.4908580033228307
For values of alpha =  0.001 The log loss is: 0.5213664721461834
For values of alpha =  0.01 The log loss is: 0.5571816816845218
For values of alpha =  0.1 The log loss is: 0.5883634494015635
For values of alpha =  1 The log loss is: 0.6090331617293725
For values of alpha =  10 The log loss is: 0.6282824182183036
```



Alpha i's

```
For values of best alpha =  0.0001 The train log loss is: 0.48201727349939166
For values of best alpha =  0.0001 The test log loss is: 0.4908580033228307
Total number of data points : 30000
```



4.6 XGBoost

In [119]:

```python
import xgboost as xgb
params = {}
params['objective'] = 'binary:logistic'
params['eval_metric'] = 'logloss'
params['eta'] = 0.02
params['max_depth'] = 4

a = [int(x) for x in y_train.values]
train_dup = np.array(a)

b = [int(x) for x in y_test.values]
test_dup = np.array(b)

d_train = xgb.DMatrix(X_train, label=train_dup)
d_test = xgb.DMatrix(X_test, label=test_dup)

watchlist = [(d_train, 'train'), (d_test, 'valid')]

bst = xgb.train(params, d_train, 400, watchlist, early_stopping_rounds=20, verbose_eval=10)

xgdmat = xgb.DMatrix(X_train,train_dup)
predict_y = bst.predict(d_test)
print("The test log loss is:",log_loss(y_test, predict_y, labels=clf.classes_, eps=1e-15))
```

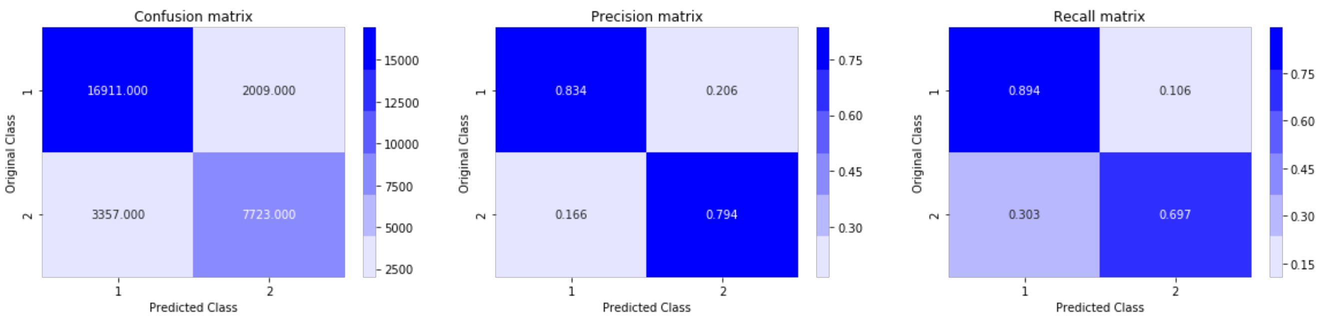
```
[0] train-logloss:0.684907 valid-logloss:0.684934
Multiple eval metrics have been passed: 'valid-logloss' will be used for early stopping.

Will train until valid-logloss hasn't improved in 20 rounds.
[10] train-logloss:0.616249 valid-logloss:0.61626
[20] train-logloss:0.56586 valid-logloss:0.566067
[30] train-logloss:0.528146 valid-logloss:0.528586
[40] train-logloss:0.498831 valid-logloss:0.499504
[50] train-logloss:0.475844 valid-logloss:0.476739
[60] train-logloss:0.457201 valid-logloss:0.458375
[70] train-logloss:0.442229 valid-logloss:0.443649
[80] train-logloss:0.430224 valid-logloss:0.431898
[90] train-logloss:0.420647 valid-logloss:0.422527
[100] train-logloss:0.412566 valid-logloss:0.414638
[110] train-logloss:0.405799 valid-logloss:0.408043
[120] train-logloss:0.399885 valid-logloss:0.402354
[130] train-logloss:0.395166 valid-logloss:0.39785
[140] train-logloss:0.391105 valid-logloss:0.394
[150] train-logloss:0.387341 valid-logloss:0.390509
[160] train-logloss:0.384229 valid-logloss:0.387663
[170] train-logloss:0.381455 valid-logloss:0.385151
[180] train-logloss:0.378872 valid-logloss:0.38284
[190] train-logloss:0.376388 valid-logloss:0.380667
[200] train-logloss:0.373915 valid-logloss:0.378531
[210] train-logloss:0.37163 valid-logloss:0.376471
[220] train-logloss:0.369511 valid-logloss:0.374671
[230] train-logloss:0.367236 valid-logloss:0.37273
[240] train-logloss:0.365281 valid-logloss:0.371155
```

```
[240] train-logloss:0.365281 valid-logloss:0.371155
[250] train-logloss:0.363534 valid-logloss:0.369782
[260] train-logloss:0.361928 valid-logloss:0.368499
[270] train-logloss:0.360334 valid-logloss:0.367261
[280] train-logloss:0.359008 valid-logloss:0.366299
[290] train-logloss:0.357615 valid-logloss:0.365268
[300] train-logloss:0.356316 valid-logloss:0.364323
[310] train-logloss:0.354945 valid-logloss:0.363287
[320] train-logloss:0.353592 valid-logloss:0.362379
[330] train-logloss:0.35234 valid-logloss:0.361485
[340] train-logloss:0.351101 valid-logloss:0.360633
[350] train-logloss:0.349969 valid-logloss:0.359867
[360] train-logloss:0.348882 valid-logloss:0.359144
[370] train-logloss:0.347718 valid-logloss:0.35837
[380] train-logloss:0.346699 valid-logloss:0.35774
[390] train-logloss:0.345597 valid-logloss:0.357061
[399] train-logloss:0.34469 valid-logloss:0.356497
The test log loss is: 0.35649735669676447
```

In [120]:

```python
predicted_y =np.array(predict_y>0.5,dtype=int)
print("Total number of data points :", len(predicted_y))
plot_confusion_matrix(y_test, predicted_y)
```

```
Total number of data points : 30000
```



5. Assignments

1. Try out models (Logistic regression, Linear-SVM) with simple TF-IDF vectors instead of TD_IDF weighted word2Vec.
2. Hyperparameter tune XgBoost using RandomSearch to reduce the log-loss.

Logistic regression, Linear-SVM with simple TF-IDF vectors

In [3]:

```python
# avoid decoding problems
df = pd.read_csv("train.csv")

# encode questions to unicode
# https://stackoverflow.com/a/6812069
# ----------------- python 2 ---------------------
# df['question1'] = df['question1'].apply(lambda x: unicode(str(x),"utf-8"))
# df['question2'] = df['question2'].apply(lambda x: unicode(str(x),"utf-8"))
# ----------------- python 3 ---------------------
df['question1'] = df['question1'].apply(lambda x: str(x))
df['question2'] = df['question2'].apply(lambda x: str(x))
```

In [4]:

```python
df.head()
```

Out[4]:

	id	qid1	qid2	question1	question2	is_duplicate

	id	qid1	qid2	question1	question2	is_duplicate
0	0	1	2	What is the step by step guide to invest in sh...	What is the step by step guide to invest in sh...	0
1	1	3	4	What is the story of Kohinoor (Koh-i-Noor) Dia...	What would happen if the Indian government sto...	0
2	2	5	6	How can I increase the speed of my internet co...	How can Internet speed be increased by hacking...	0
3	3	7	8	Why am I mentally very lonely? How can I solve...	Find the remainder when [math]23^{24}[/math] i...	0
4	4	9	10	Which one dissolve in water quikly sugar, salt...	Which fish would survive in salt water?	0

In [5]:

```
#prepro_features_train.csv (Simple Preprocessing Feartures)
#nlp_features_train.csv (NLP Features)
if os.path.isfile('nlp_features_train.csv'):
    dfnlp = pd.read_csv("nlp_features_train.csv",encoding='latin-1')
else:
    print("download nlp_features_train.csv from drive or run previous notebook")

if os.path.isfile('df_fe_without_preprocessing_train.csv'):
    dfppro = pd.read_csv("df_fe_without_preprocessing_train.csv",encoding='latin-1')
else:
    print("download df_fe_without_preprocessing_train.csv from drive or run previous notebook")
```

In [6]:

```
# NLP features
df1 = dfnlp.drop(['qid1','qid2','question1','question2','is_duplicate'],axis=1)
# Preprocessing features
df2 = dfppro.drop(['qid1','qid2','question1','question2','is_duplicate'],axis=1)
print(df1.shape)
print(df2.shape)
```

```
(404290, 16)
(404290, 12)
```

In [7]:

```
df3 = pd.merge(df1, df2, how='inner', on = 'id')
df3.head()
```

Out[7]:

	id	cwc_min	cwc_max	csc_min	csc_max	ctc_min	ctc_max	last_word_eq	first_word_eq	abs_len_diff	...	freq_qid2	q1len	q2l
0	0	0.999980	0.833319	0.999983	0.999983	0.916659	0.785709	0.0	1.0	2.0	...	1	66	
1	1	0.799984	0.399996	0.749981	0.599988	0.699993	0.466664	0.0	1.0	5.0	...	1	51	
2	2	0.399992	0.333328	0.399992	0.249997	0.399996	0.285712	0.0	1.0	4.0	...	1	73	
3	3	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0	0.0	2.0	...	1	50	
4	4	0.399992	0.199998	0.999950	0.666644	0.571420	0.307690	0.0	1.0	6.0	...	1	76	

5 rows × 27 columns

In [8]:

```
df_final = pd.merge(df, df3, how='inner', on = 'id')
df_final.head()
```

Out[8]:

	id	qid1	qid2	question1	question2	is_duplicate	cwc_min	cwc_max	csc_min	csc_max	...	freq_qid2	q1len	q2len	q1_n_wo
0	0	1	2	What is the step by step guide to invest in sh	What is the step by step guide to invest in sh...	0	0.999980	0.833319	0.999983	0.999983	...	1	66	57	

	id	qid1	qid2	question1	question2	is_duplicate	cwc_min	cwc_max	csc_min	csc_max	...	freq_qid2	q1len	q2len	q1_n_wc
1	1	3	4	What is the story of Kohinoor (Koh-i-Noor) Dia...	What would happen if the Indian government sto...	0	0.799984	0.399996	0.749981	0.599988	...	1	51	88	
2	2	5	6	How can I increase the speed of my internet co...	How can Internet speed be increased by hacking...	0	0.399992	0.333328	0.399992	0.249997	...	1	73	59	
3	3	7	8	Why am I mentally very lonely? How can I solve...	Find the remainder when [math]23^{24}[/math] i...	0	0.000000	0.000000	0.000000	0.000000	...	1	50	65	
4	4	9	10	Which one dissolve in water quikly sugar, salt...	Which fish would survive in salt water?	0	0.399992	0.199998	0.999950	0.666644	...	1	76	39	

5 rows × 32 columns

In [9]:

```
from sklearn.model_selection import train_test_split
Quora_train, Quora_test, isDuplicate_train, isDuplicate_test = train_test_split(df_final, df_final[
'is_duplicate'], test_size=0.33, stratify=df_final['is_duplicate'])
Quora_train, Quora_cv, isDuplicate_train, isDuplicate_cv = train_test_split(Quora_train, isDuplicat
e_train, test_size=0.33, stratify=isDuplicate_train)
```

In [10]:

```
print(Quora_train.shape,isDuplicate_train.shape)
print(Quora_test.shape,isDuplicate_test.shape)
print(Quora_cv.shape,isDuplicate_cv.shape)
df_final.columns
```

```
(181485, 32) (181485,)
(133416, 32) (133416,)
(89389, 32) (89389,)
```

Out[10]:

```
Index(['id', 'qid1', 'qid2', 'question1', 'question2', 'is_duplicate',
       'cwc_min', 'cwc_max', 'csc_min', 'csc_max', 'ctc_min', 'ctc_max',
       'last_word_eq', 'first_word_eq', 'abs_len_diff', 'mean_len',
       'token_set_ratio', 'token_sort_ratio', 'fuzz_ratio',
       'fuzz_partial_ratio', 'longest_substr_ratio', 'freq_qid1', 'freq_qid2',
       'q1len', 'q2len', 'q1_n_words', 'q2_n_words', 'word_Common',
       'word_Total', 'word_share', 'freq_q1+q2', 'freq_q1-q2'],
      dtype='object')
```

TFIDF vectorization

In [11]:

```
%%time
from sklearn.feature_extraction.text import TfidfVectorizer

vectorizer_Q1_TDIDF = TfidfVectorizer()
vectorizer_Q1_TDIDF.fit(Quora_train['question1'].values) # fit has to happen only on train data

Quora_train_tfidf = vectorizer_Q1_TDIDF.transform(Quora_train['question1'].values)
Quora_cv_tfidf = vectorizer_Q1_TDIDF.transform(Quora_cv['question1'].values)
Quora_test_tfidf = vectorizer_Q1_TDIDF.transform(Quora_test['question1'].values)

print("After vectorizing Quora Question 1 to TFIDF")
```

```
print("After vectorizing Quora Question 1 to TFIDF")
print(Quora_train_tfidf.shape, isDuplicate_train.shape)
print(Quora_cv_tfidf.shape, isDuplicate_cv.shape)
print(Quora_test_tfidf.shape, isDuplicate_test.shape)
print("="*100)
```

```
After vectorizing Quora Question 1 to TFIDF
(181485, 47987) (181485,)
(89389, 47987) (89389,)
(133416, 47987) (133416,)
====================================================================================================

Wall time: 6.06 s
```

In [12]:

```
%%time
from sklearn.feature_extraction.text import TfidfVectorizer

vectorizer_Q2_TDIDF = TfidfVectorizer()
vectorizer_Q2_TDIDF.fit(Quora_train['question2'].values) # fit has to happen only on train data

Quora_train_tfidf_Q2 = vectorizer_Q2_TDIDF.transform(Quora_train['question2'].values)
Quora_cv_tfidf_Q2 = vectorizer_Q2_TDIDF.transform(Quora_cv['question2'].values)
Quora_test_tfidf_Q2 = vectorizer_Q2_TDIDF.transform(Quora_test['question2'].values)

print("After vectorizing Quora Question 2 to TFIDF")
print(Quora_train_tfidf_Q2.shape, isDuplicate_train.shape)
print(Quora_cv_tfidf_Q2.shape, isDuplicate_cv.shape)
print(Quora_test_tfidf_Q2.shape, isDuplicate_test.shape)
print("="*100)
```

```
After vectorizing Quora Question 2 to TFIDF
(181485, 44233) (181485,)
(89389, 44233) (89389,)
(133416, 44233) (133416,)
====================================================================================================

Wall time: 5.99 s
```

Numerical features

In [13]:

```
from sklearn.preprocessing import Normalizer
normalizer = Normalizer()
normalizer.fit(Quora_train['cwc_min'].values.reshape(-1,1))
Quora_train_cwc_min = normalizer.transform(Quora_train['cwc_min'].values.reshape(-1,1))
Quora_cv_cwc_min = normalizer.transform(Quora_cv['cwc_min'].values.reshape(-1,1))
Quora_test_cwc_min  = normalizer.transform(Quora_test['cwc_min'].values.reshape(-1,1))
```

In [14]:

```
normalizer.fit(Quora_train['cwc_max'].values.reshape(-1,1))
Quora_train_cwc_max = normalizer.transform(Quora_train['cwc_max'].values.reshape(-1,1))
Quora_cv_cwc_max = normalizer.transform(Quora_cv['cwc_max'].values.reshape(-1,1))
Quora_test_cwc_max = normalizer.transform(Quora_test['cwc_max'].values.reshape(-1,1))
```

In [15]:

```
normalizer.fit(Quora_train['csc_min'].values.reshape(-1,1))
Quora_train_csc_min = normalizer.transform(Quora_train['csc_min'].values.reshape(-1,1))
Quora_cv_csc_min = normalizer.transform(Quora_cv['csc_min'].values.reshape(-1,1))
Quora_test_csc_min  = normalizer.transform(Quora_test['csc_min'].values.reshape(-1,1))
```

In [16]:

```
normalizer.fit(Quora_train['csc_max'].values.reshape(-1,1))
Quora_train_csc_max = normalizer.transform(Quora_train['csc_max'].values.reshape(-1,1))
Quora_cv_csc_max = normalizer.transform(Quora_cv['csc_max'].values.reshape(-1,1))
```

```
Quora_cv_csc_max = normalizer.transform(Quora_cv['csc_max'].values.reshape(-1,1))
Quora_test_csc_max  = normalizer.transform(Quora_test['csc_max'].values.reshape(-1,1))
```

In [17]:

```
normalizer.fit(Quora_train['ctc_min'].values.reshape(-1,1))
Quora_train_ctc_min = normalizer.transform(Quora_train['ctc_min'].values.reshape(-1,1))
Quora_cv_ctc_min = normalizer.transform(Quora_cv['ctc_min'].values.reshape(-1,1))
Quora_test_ctc_min  = normalizer.transform(Quora_test['ctc_min'].values.reshape(-1,1))
```

In [18]:

```
normalizer.fit(Quora_train['ctc_max'].values.reshape(-1,1))
Quora_train_ctc_max = normalizer.transform(Quora_train['ctc_max'].values.reshape(-1,1))
Quora_cv_ctc_max = normalizer.transform(Quora_cv['ctc_max'].values.reshape(-1,1))
Quora_test_ctc_max = normalizer.transform(Quora_test['ctc_max'].values.reshape(-1,1))
```

In [19]:

```
normalizer.fit(Quora_train['token_set_ratio'].values.reshape(-1,1))
Quora_train_tsr = normalizer.transform(Quora_train['token_set_ratio'].values.reshape(-1,1))
Quora_cv_tsr = normalizer.transform(Quora_cv['token_set_ratio'].values.reshape(-1,1))
Quora_test_tsr = normalizer.transform(Quora_test['token_set_ratio'].values.reshape(-1,1))
```

In [20]:

```
normalizer.fit(Quora_train['token_sort_ratio'].values.reshape(-1,1))
Quora_train_tstr = normalizer.transform(Quora_train['token_sort_ratio'].values.reshape(-1,1))
Quora_cv_tstr = normalizer.transform(Quora_cv['token_sort_ratio'].values.reshape(-1,1))
Quora_test_tstr= normalizer.transform(Quora_test['token_sort_ratio'].values.reshape(-1,1))
```

In [21]:

```
normalizer.fit(Quora_train['fuzz_ratio'].values.reshape(-1,1))
Quora_train_fr = normalizer.transform(Quora_train['fuzz_ratio'].values.reshape(-1,1))
Quora_cv_fr = normalizer.transform(Quora_cv['fuzz_ratio'].values.reshape(-1,1))
Quora_test_fr= normalizer.transform(Quora_test['fuzz_ratio'].values.reshape(-1,1))
```

In [22]:

```
normalizer.fit(Quora_train['fuzz_partial_ratio'].values.reshape(-1,1))
Quora_train_fpr = normalizer.transform(Quora_train['fuzz_partial_ratio'].values.reshape(-1,1))
Quora_cv_fpr = normalizer.transform(Quora_cv['fuzz_partial_ratio'].values.reshape(-1,1))
Quora_test_fpr= normalizer.transform(Quora_test['fuzz_partial_ratio'].values.reshape(-1,1))
```

In [23]:

```
normalizer.fit(Quora_train['word_Common'].values.reshape(-1,1))
Quora_train_wc = normalizer.transform(Quora_train['word_Common'].values.reshape(-1,1))
Quora_cv_wc = normalizer.transform(Quora_cv['word_Common'].values.reshape(-1,1))
Quora_test_wc= normalizer.transform(Quora_test['word_Common'].values.reshape(-1,1))
```

In [24]:

```
normalizer.fit(Quora_train['word_share'].values.reshape(-1,1))
Quora_train_ws = normalizer.transform(Quora_train['word_share'].values.reshape(-1,1))
Quora_cv_ws = normalizer.transform(Quora_cv['word_share'].values.reshape(-1,1))
Quora_test_ws = normalizer.transform(Quora_test['word_share'].values.reshape(-1,1))
```

In [25]:

```
normalizer.fit(Quora_train['longest_substr_ratio'].values.reshape(-1,1))
Quora_train_lsr = normalizer.transform(Quora_train['longest_substr_ratio'].values.reshape(-1,1))
Quora_cv_lsr = normalizer.transform(Quora_cv['longest_substr_ratio'].values.reshape(-1,1))
Quora_test_lsr = normalizer.transform(Quora_test['longest_substr_ratio'].values.reshape(-1,1))
```

In [26]:

```
normalizer.fit(Quora_train['word_Total'].values.reshape(-1,1))
Quora_train_wt = normalizer.transform(Quora_train['word_Total'].values.reshape(-1,1))
Quora_cv_wt = normalizer.transform(Quora_cv['word_Total'].values.reshape(-1,1))
Quora_test_wt = normalizer.transform(Quora_test['word_Total'].values.reshape(-1,1))
```

In [27]:

```
normalizer.fit(Quora_train['freq_q1+q2'].values.reshape(-1,1))
Quora_train_fq1q2 = normalizer.transform(Quora_train['freq_q1+q2'].values.reshape(-1,1))
Quora_cv_fq1q2 = normalizer.transform(Quora_cv['freq_q1+q2'].values.reshape(-1,1))
Quora_test_fq1q2 = normalizer.transform(Quora_test['freq_q1+q2'].values.reshape(-1,1))
```

In [28]:

```
normalizer.fit(Quora_train['freq_q1-q2'].values.reshape(-1,1))
Quora_train_fq1_q2 = normalizer.transform(Quora_train['freq_q1-q2'].values.reshape(-1,1))
Quora_cv_fq1_q2 = normalizer.transform(Quora_cv['freq_q1-q2'].values.reshape(-1,1))
Quora_test_fq1_q2 = normalizer.transform(Quora_test['freq_q1-q2'].values.reshape(-1,1))
```

In [29]:

```
normalizer.fit(Quora_train['abs_len_diff'].values.reshape(-1,1))
Quora_train_ald = normalizer.transform(Quora_train['abs_len_diff'].values.reshape(-1,1))
Quora_cv_ald = normalizer.transform(Quora_cv['abs_len_diff'].values.reshape(-1,1))
Quora_test_ald = normalizer.transform(Quora_test['abs_len_diff'].values.reshape(-1,1))
```

In [30]:

```
# Merging all features using hstack

from scipy.sparse import hstack
FinalQuora_tr_tfidf = hstack((Quora_train_lsr,Quora_train_wt,Quora_train_fq1q2,Quora_train_fq1_q2,
Quora_train_ald,Quora_train_cwc_min,Quora_train_cwc_max,Quora_train_csc_min,Quora_train_csc_max,Quo
ra_train_ctc_min,Quora_train_ctc_max,Quora_train_tsr,Quora_train_tstr,Quora_train_fr,Quora_train_fp
r,Quora_train_wc,Quora_train_ws,Quora_train_tfidf,Quora_train_tfidf_Q2)).tocsr()
FinalQuora_cv_tfidf = hstack((Quora_cv_lsr,Quora_cv_wt,Quora_cv_fq1q2,Quora_cv_fq1_q2,Quora_cv_ald
,Quora_cv_cwc_min,Quora_cv_cwc_max,Quora_cv_csc_min,Quora_cv_csc_max,Quora_cv_ctc_min,Quora_cv_ctc_
max,Quora_cv_tsr,Quora_cv_tstr,Quora_cv_fr,Quora_cv_fpr,Quora_cv_wc,Quora_cv_ws,Quora_cv_tfidf,Quor
a_cv_tfidf_Q2)).tocsr()
FinalQuora_te_tfidf =
hstack((Quora_test_lsr,Quora_test_wt,Quora_test_fq1q2,Quora_test_fq1_q2,Quora_test_ald,Quora_test_c
wc_min,Quora_test_cwc_max,Quora_test_csc_min,Quora_test_csc_max,Quora_test_ctc_min,Quora_test_ctc_m
ax,Quora_test_tsr,Quora_test_tstr,Quora_test_fr,Quora_test_fpr,Quora_test_wc,Quora_test_ws,Quora_te
st_tfidf,Quora_test_tfidf_Q2)).tocsr()

print("Final Donor Data Matrix for Set 1")
print(FinalQuora_tr_tfidf.shape,isDuplicate_train.shape)
print(FinalQuora_cv_tfidf.shape,isDuplicate_cv.shape)
print(FinalQuora_te_tfidf.shape,isDuplicate_test.shape)
print("="*100)
```

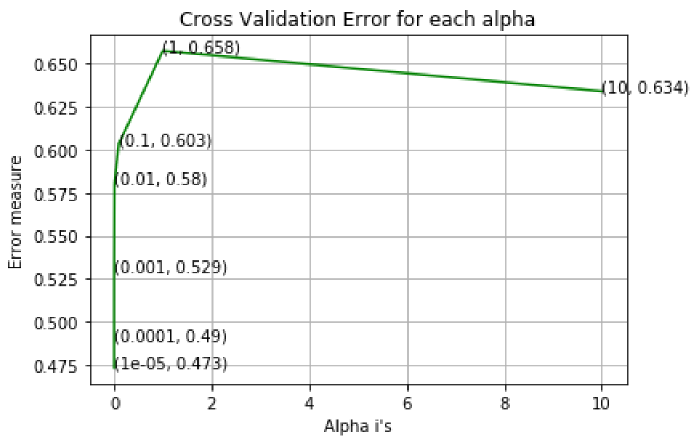
```
Final Donor Data Matrix for Set 1
(181485, 92237) (181485,)
(89389, 92237) (89389,)
(133416, 92237) (133416,)
====================================================================================================
```

In [31]:

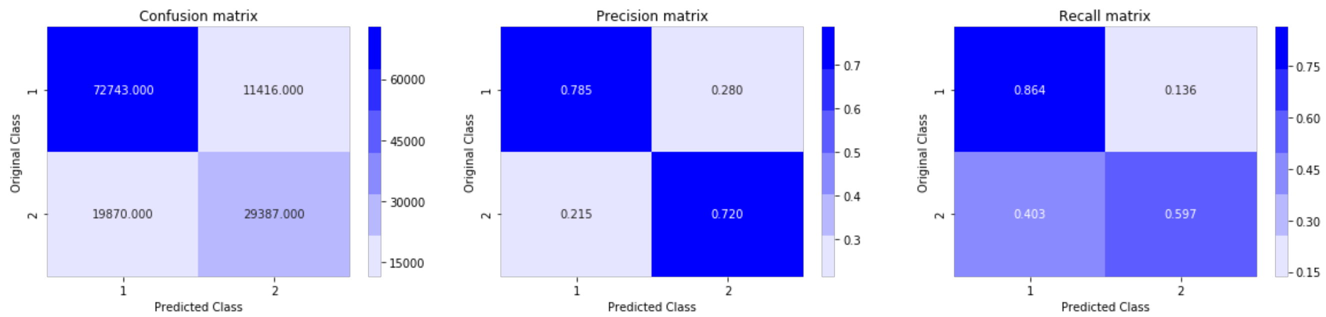
```
alpha = [10 ** x for x in range(-5, 2)] # hyperparam for SGD classifier.

log_error_array_tfidf = []
for i in alpha:
    clf_tdidf = SGDClassifier(alpha=i, penalty='l2', loss='log', random_state=42)
    clf_tdidf.fit(FinalQuora_tr_tfidf, isDuplicate_train)
    sig_clf_tdidf = CalibratedClassifierCV(clf_tdidf, method="sigmoid")
    sig_clf_tdidf.fit(FinalQuora_tr_tfidf, isDuplicate_train)
    predict_y = sig_clf_tdidf.predict_proba(FinalQuora_te_tfidf)
    log_error_array_tfidf.append(log_loss(isDuplicate_test, predict_y, labels=clf_tdidf.classes_, e
ps=1e-15))
```

```
    print('For values of alpha = ', i, "The log loss is:",log_loss(isDuplicate_test, predict_y, lab
els=clf_tdidf.classes_, eps=1e-15))

fig, ax = plt.subplots()
ax.plot(alpha, log_error_array_tfidf,c='g')
for i, txt in enumerate(np.round(log_error_array_tfidf,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],log_error_array_tfidf[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show()


best_alpha = np.argmin(log_error_array_tfidf)
clf_tdidf = SGDClassifier(alpha=alpha[best_alpha], penalty='l2', loss='log', random_state=42)
clf_tdidf.fit(FinalQuora_tr_tfidf, isDuplicate_train)
sig_clf_tdidf = CalibratedClassifierCV(clf_tdidf, method="sigmoid")
sig_clf_tdidf.fit(FinalQuora_tr_tfidf, isDuplicate_train)

predict_y = sig_clf_tdidf.predict_proba(FinalQuora_tr_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss
is:",log_loss(isDuplicate_train, predict_y, labels=clf_tdidf.classes_, eps=1e-15))
predict_y = sig_clf_tdidf.predict_proba(FinalQuora_te_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss
is:",log_loss(isDuplicate_test, predict_y, labels=clf_tdidf.classes_, eps=1e-15))
predicted_y =np.argmax(predict_y,axis=1)
print("Total number of data points :", len(predicted_y))
plot_confusion_matrix(isDuplicate_test, predicted_y)
```

```
For values of alpha =  1e-05 The log loss is: 0.47320064888359764
For values of alpha =  0.0001 The log loss is: 0.48970976636414243
For values of alpha =  0.001 The log loss is: 0.529464668078801
For values of alpha =  0.01 The log loss is: 0.5804794886129548
For values of alpha =  0.1 The log loss is: 0.6034265145239367
For values of alpha =  1 The log loss is: 0.6575599332858357
For values of alpha =  10 The log loss is: 0.6340229608053409
```




```
For values of best alpha =  1e-05 The train log loss is: 0.4336526622679598
For values of best alpha =  1e-05 The test log loss is: 0.47320064888359764
Total number of data points : 133416
```

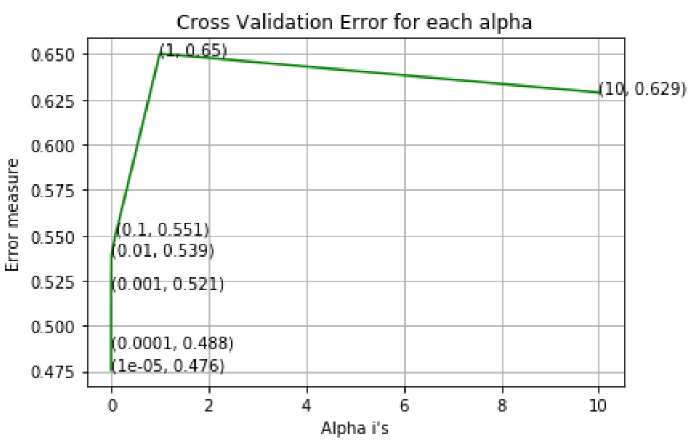


In [44]:

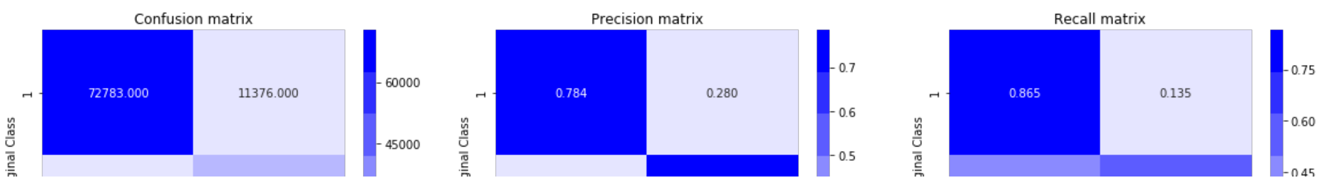
```
alpha = [10 ** x for x in range(-5, 2)] # hyperparam for SGD classifier.
```

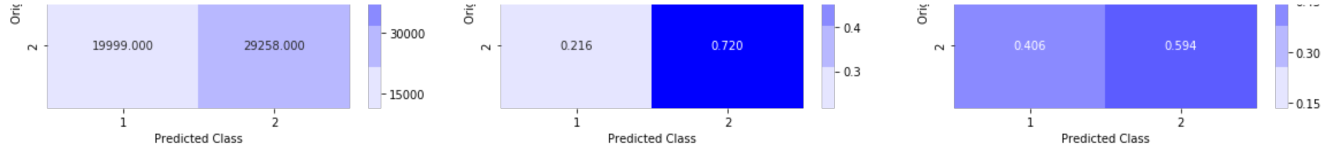
```
log_error_array_tfidf = []
for i in alpha:
    clf_tdidf = SGDClassifier(alpha=i, penalty='l2', loss='hinge', random_state=42)
    clf_tdidf.fit(FinalQuora_tr_tfidf, isDuplicate_train)
    sig_clf_tdidf = CalibratedClassifierCV(clf_tdidf, method="sigmoid")
    sig_clf_tdidf.fit(FinalQuora_tr_tfidf, isDuplicate_train)
    predict_y = sig_clf_tdidf.predict_proba(FinalQuora_te_tfidf)
    log_error_array_tfidf.append(log_loss(isDuplicate_test, predict_y, labels=clf_tdidf.classes_, e
ps=1e-15))
    print('For values of alpha = ', i, "The log loss is:",log_loss(isDuplicate_test, predict_y, lab
els=clf_tdidf.classes_, eps=1e-15))

fig, ax = plt.subplots()
ax.plot(alpha, log_error_array_tfidf,c='g')
for i, txt in enumerate(np.round(log_error_array_tfidf,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],log_error_array_tfidf[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show()


best_alpha = np.argmin(log_error_array_tfidf)
clf_tdidf = SGDClassifier(alpha=alpha[best_alpha], penalty='l2', loss='hinge', random_state=42)
clf_tdidf.fit(FinalQuora_tr_tfidf, isDuplicate_train)
sig_clf_tdidf = CalibratedClassifierCV(clf_tdidf, method="sigmoid")
sig_clf_tdidf.fit(FinalQuora_tr_tfidf, isDuplicate_train)

predict_y = sig_clf_tdidf.predict_proba(FinalQuora_tr_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss
is:",log_loss(isDuplicate_train, predict_y, normalize=True, eps=1e-15))
predict_y = sig_clf_tdidf.predict_proba(FinalQuora_te_tfidf)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss
is:",log_loss(isDuplicate_test, predict_y, normalize=True, eps=1e-15))
predicted_y =np.argmax(predict_y,axis=1)
print("Total number of data points :", len(predicted_y))
plot_confusion_matrix(isDuplicate_test, predicted_y)
```

```
For values of alpha =  1e-05 The log loss is: 0.4756270592491547
For values of alpha =  0.0001 The log loss is: 0.4883877732860549
For values of alpha =  0.001 The log loss is: 0.5206307887737196
For values of alpha =  0.01 The log loss is: 0.5392722575399467
For values of alpha =  0.1 The log loss is: 0.5506889259583466
For values of alpha =  1 The log loss is: 0.6501838275645053
For values of alpha =  10 The log loss is: 0.6286721557885355
```




```
For values of best alpha =  1e-05 The train log loss is: 0.43782110317985934
For values of best alpha =  1e-05 The test log loss is: 0.4756270592491547
Total number of data points : 133416
```





Hyperparameter tune XgBoost using RandomSearch to reduce the log-loss.

In [37]:

```
import xgboost as xgb
from scipy import stats
import random
from scipy.stats import randint
from sklearn.model_selection import RandomizedSearchCV
from sklearn.metrics import log_loss

clf_xgb = xgb.XGBClassifier(objective = 'binary:logistic')

params = {}
params['n_estimators'] = stats.randint(50, 600)
params['max_depth'] = stats.randint(3, 10)

clf_xgb_tfidf = RandomizedSearchCV(clf_xgb, param_distributions = params, n_iter = 10, scoring = 'n
eg_log_loss')
clf_xgb_tfidf.fit(FinalQuora_tr_tfidf, isDuplicate_train)
```

Out[37]:

```
RandomizedSearchCV(cv='warn', error_score='raise-deprecating',
          estimator=XGBClassifier(base_score=0.5, booster='gbtree', colsample_bylevel=1,
       colsample_bynode=1, colsample_bytree=1, gamma=0, learning_rate=0.1,
       max_delta_step=0, max_depth=3, min_child_weight=1, missing=None,
       n_estimators=100, n_jobs=1, nthread=None,
       objective='binary:logistic', random_state=0, reg_alpha=0,
       reg_lambda=1, scale_pos_weight=1, seed=None, silent=None,
       subsample=1, verbosity=1),
          fit_params=None, iid='warn', n_iter=10, n_jobs=None,
          param_distributions={'n_estimators': <scipy.stats._distn_infrastructure.rv_frozen object
at 0x000001E6D9C38198>, 'max_depth': <scipy.stats._distn_infrastructure.rv_frozen object at
0x000001E6D9C380F0>},
          pre_dispatch='2*n_jobs', random_state=None, refit=True,
          return_train_score='warn', scoring='neg_log_loss', verbose=0)
```

In [48]:

```
clf_xgb_tfidf.best_estimator_
```

Out[48]:

```
XGBClassifier(base_score=0.5, booster='gbtree', colsample_bylevel=1,
       colsample_bynode=1, colsample_bytree=1, gamma=0, learning_rate=0.1,
       max_delta_step=0, max_depth=8, min_child_weight=1, missing=None,
       n_estimators=459, n_jobs=1, nthread=None,
       objective='binary:logistic', random_state=0, reg_alpha=0,
       reg_lambda=1, scale_pos_weight=1, seed=None, silent=None,
       subsample=1, verbosity=1)
```

In [41]:

```
clf_xgb_tfidf.cv_results_
```

Out[41]:

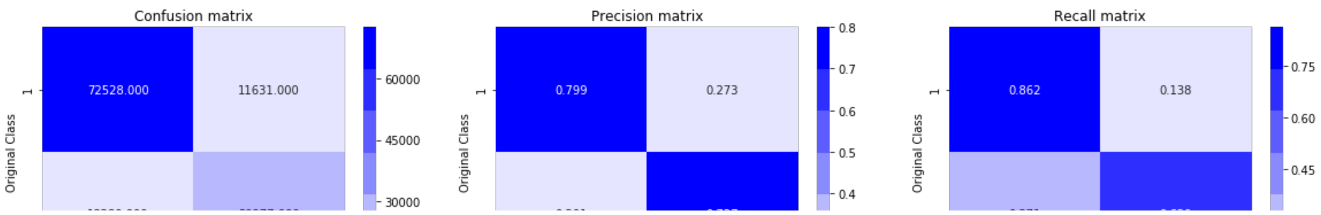
```
{'mean_fit_time': array([389.24354426, 367.32498153, 301.50068601, 650.03729026,
        311.98088058, 140.62370165, 277.395015  , 169.24964905,
        383.9708813 , 423.66160583]),
 'std_fit_time': array([ 0.15705635,  1.08776727,  2.35244347, 13.29834526,  2.83479395,
         2.50480307,  7.00384762,  0.26943906,  0.58090486,  0.72279985]),
 'mean_score_time': array([1.54917773, 1.57702764, 1.27605255, 2.64232437, 1.4765652 ,
        0.9226052 , 1.17570114, 0.87939167, 1.78640763, 1.76931564]),
```

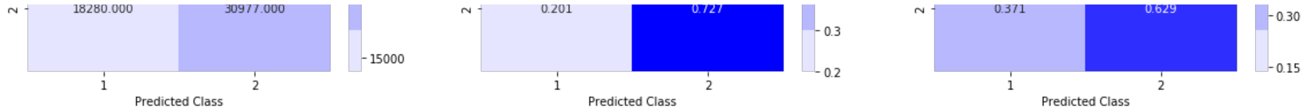
```
 'std_score_time': array([0.06295424, 0.01342454, 0.03733585, 0.06109798, 0.04020179,
        0.03305707, 0.01817125, 0.00538533, 0.01956651, 0.00482308]),
 'param_max_depth': masked_array(data=[4, 6, 3, 8, 6, 5, 4, 3, 9, 5],
              mask=[False, False, False, False, False, False, False, False,
                    False, False],
        fill_value='?',
             dtype=object),
 'param_n_estimators': masked_array(data=[561, 335, 528, 459, 283, 156, 392, 330, 261, 516],
              mask=[False, False, False, False, False, False, False, False,
                    False, False],
        fill_value='?',
             dtype=object),
 'params': [{'max_depth': 4, 'n_estimators': 561},
  {'max_depth': 6, 'n_estimators': 335},
  {'max_depth': 3, 'n_estimators': 528},
  {'max_depth': 8, 'n_estimators': 459},
  {'max_depth': 6, 'n_estimators': 283},
  {'max_depth': 5, 'n_estimators': 156},
  {'max_depth': 4, 'n_estimators': 392},
  {'max_depth': 3, 'n_estimators': 330},
  {'max_depth': 9, 'n_estimators': 261},
  {'max_depth': 5, 'n_estimators': 516}],
 'split0_test_score': array([-0.4756761 , -0.47259568, -0.48762026, -0.45555731, -0.47666342,
        -0.49801208, -0.48356229, -0.49910233, -0.4621058 , -0.46940756]),
 'split1_test_score': array([-0.47774858, -0.47360759, -0.48974958, -0.45654485, -0.4773762 ,
        -0.49952684, -0.48569191, -0.5002271 , -0.46405986, -0.47119285]),
 'split2_test_score': array([-0.47834043, -0.47543327, -0.49045384, -0.4573283 , -0.47900474,
        -0.49973076, -0.48609904, -0.50107838, -0.46457047, -0.47209485]),
 'mean_test_score': array([-0.47725502, -0.47387883, -0.48927454, -0.45647681, -0.47768144,
        -0.49908989, -0.48511773, -0.50013593, -0.46357869, -0.4708984 ]),
 'std_test_score': array([0.00114233, 0.00117421, 0.00120458, 0.0007246 , 0.0009799 ,
        0.00076667, 0.00111236, 0.00080929, 0.00106216, 0.00111666]),
 'rank_test_score': array([ 5,  4,  8,  1,  6,  9,  7, 10,  2,  3]),
 'split0_train_score': array([-0.45544045, -0.44528684, -0.47607367, -0.40142649, -0.45264862,
        -0.48791894, -0.46867503, -0.49194847, -0.41644544, -0.44116032]),
 'split1_train_score': array([-0.45516612, -0.44328027, -0.47605305, -0.39972196, -0.45018313,
        -0.48715946, -0.46835567, -0.49077509, -0.41479297, -0.44071052]),
 'split2_train_score': array([-0.45343402, -0.4439584 , -0.47540412, -0.39836775, -0.45086481,
        -0.48615055, -0.46703878, -0.49039494, -0.4120641 , -0.4397144 ]),
 'mean_train_score': array([-0.4546802 , -0.44417517, -0.47584361, -0.39983873, -0.45123219,
        -0.48707632, -0.46802316, -0.4910395 , -0.41443417, -0.44052842]),
 'std_train_score': array([0.00088827, 0.00083339, 0.00031088, 0.00125145, 0.00103951,
        0.00072433, 0.00070817, 0.00066121, 0.00180658, 0.00060418])}
```

In [52]:

```
%%time
# Best Estimators : max_depth=8, n_estimators=459,

log_loss_xgbModel = []

xgbModel = xgb.XGBClassifier(objective = 'binary:logistic',max_depth=8, min_child_weight=1, missing
=None, n_estimators=459)
sig_clf_xgb_tfidf = CalibratedClassifierCV(xgbModel, method="sigmoid")
sig_clf_xgb_tfidf.fit(FinalQuora_tr_tfidf, isDuplicate_train)
predict_y = sig_clf_xgb_tfidf.predict_proba(FinalQuora_tr_tfidf)
print("The train log loss is:",log_loss(isDuplicate_train, predict_y, normalize=True, eps=1e-15))
predict_y = sig_clf_xgb_tfidf.predict_proba(FinalQuora_te_tfidf)
print("The test log loss is:",log_loss(isDuplicate_test, predict_y, normalize=True, eps=1e-15))
predicted_y =np.argmax(predict_y,axis=1)
print("Total number of data points :", len(predicted_y))
plot_confusion_matrix(isDuplicate_test, predicted_y)
```

```
The train log loss is: 0.39881467600510984
The test log loss is: 0.45265138084898415
Total number of data points : 133416
```






```
Wall time: 2h 2min 33s
```

In [53]:

```python
# Try out models (Logistic regression, Linear-SVM) with simple TF-IDF vectors instead of TD_IDF we
ighted word2Vec.
# Hyperparameter tune XgBoost using RandomSearch to reduce the log-loss.


from prettytable import PrettyTable

x = PrettyTable()
x.field_names = ["Model", "Vectorizer", "Alpha", "Tree Depth","Estimators", "Total Samples", "Train
Log Loss", "Test Log Loss"]


x.add_row(["Random Model", "Random",'NaN', 'NaN', 'NaN', 30000, 'NaN', 0.893])
x.add_row(["Logistic Regression", "Random",1, 'NaN', 'NaN', 30000, 0.505, 0.510])
x.add_row(["Linear Regression", "Random",1, 'NaN', 'NaN', 30000, 0.482, 0.490])
x.add_row(["Logistic Regression", "TFIDF Vectors",'1e-05', 'NaN', 'NaN', 133416, 0.433, 0.473])
x.add_row(["Linear SVM", "TFIDF Vectors", '1e-05', 'NaN', 'NaN', 133416, 0.437, 0.475])
x.add_row(["XGBoost", "TFIDF Vectors", 'NaN', 8, 459, 133416, 0.398, 0.452 ])

print(x)
```

```
+---------------------+---------------+-------+------------+------------+---------------+----------
---+---------------+
|        Model        |   Vectorizer  | Alpha | Tree Depth | Estimators | Total Samples | Train Log
Loss | Test Log Loss |
+---------------------+---------------+-------+------------+------------+---------------+----------
---+---------------+
|     Random Model    |     Random    |  NaN  |    NaN     |    NaN     |     30000     |      NaN
|     0.893     |
| Logistic Regression |     Random    |   1   |    NaN     |    NaN     |     30000     |     0.505
|      0.51     |
|  Linear Regression  |     Random    |   1   |    NaN     |    NaN     |     30000     |     0.482
|      0.49     |
| Logistic Regression | TFIDF Vectors | 1e-05 |    NaN     |    NaN     |     133416    |     0.433
|     0.473     |
|      Linear SVM     | TFIDF Vectors | 1e-05 |    NaN     |    NaN     |     133416    |     0.437
|     0.475     |
|       XGBoost       | TFIDF Vectors |  NaN  |     8      |    459     |     133416    |     0.398
|     0.452     |
+---------------------+---------------+-------+------------+------------+---------------+----------
---+---------------+
```