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




# exctract word2vec vectors
# https://github.com/explosion/spaCy/issues/1721
# http://landinghub.visualstudio.com/visual-cpp-build-tools
import spacy
os.chdir('C:/Users/kingsubham27091995/Desktop/AppliedAiCouse/CASE
STUDIES/QuoraQuestionPairSimilarity/Quora')
```

```
C:\Users\kingsubham27091995\Anaconda3\lib\site-packages\sklearn\cross_validation.py:41:
DeprecationWarning: This module was deprecated in version 0.18 in favor of the model_selection
module into which all the refactored classes and functions are moved. Also note that the interface
of the new CV iterators are different from that of this module. This module will be removed in 0.2
0.
  "This module will be removed in 0.20.", DeprecationWarning)
C:\Users\kingsubham27091995\Anaconda3\lib\site-packages\sklearn\ensemble\weight_boosting.py:29: De
precationWarning: numpy.core.umath_tests is an internal NumPy module and should not be imported. I
t will be removed in a future NumPy release.
  from numpy.core.umath_tests import inner1d
```

4. Machine Learning Models

4.1 Reading data from file and storing into sql table

In [0]:

```
#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
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
_x','58_x','59_x','60_x','61_x','62_x','63_x','64_x','65_x','66_x','67_x','68_x','69_x','70_x','71_
x','72_x','73_x','74_x','75_x','76_x','77_x','78_x','79_x','80_x','81_x','82_x','83_x','84_x','85_x
','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'
,'100_x','101_x','102_x','103_x','104_x','105_x','106_x','107_x','108_x','109_x','110_x','111_x','
112_x','113_x','114_x','115_x','116_x','117_x','118_x','119_x','120_x','121_x','122_x','123_x','12
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x','137_x','138_x','139_x','140_x','141_x','142_x','143_x','144_x','145_x','146_x','147_x','148_x'
,'149_x','150_x','151_x','152_x','153_x','154_x','155_x','156_x','157_x','158_x','159_x','160_x','
161_x','162_x','163_x','164_x','165_x','166_x','167_x','168_x','169_x','170_x','171_x','172_x','17
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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,'198_x','199_x','200_x','201_x','202_x','203_x','204_x','205_x','206_x','207_x','208_x','209_x','
210_x','211_x','212_x','213_x','214_x','215_x','216_x','217_x','218_x','219_x','220_x','221_x','22
2_x','223_x','224_x','225_x','226_x','227_x','228_x','229_x','230_x','231_x','232_x','233_x','234_
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,'247_x','248_x','249_x','250_x','251_x','252_x','253_x','254_x','255_x','256_x','257_x','258_x','
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1_x','272_x','273_x','274_x','275_x','276_x','277_x','278_x','279_x','280_x','281_x','282_x','283_
x','284_x','285_x','286_x','287_x','288_x','289_x','290_x','291_x','292_x','293_x','294_x','295_x'
,'296_x','297_x','298_x','299_x','300_x','301_x','302_x','303_x','304_x','305_x','306_x','307_x','
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0_x','321_x','322_x','323_x','324_x','325_x','326_x','327_x','328_x','329_x','330_x','331_x','332_
x','333_x','334_x','335_x','336_x','337_x','338_x','339_x','340_x','341_x','342_x','343_x','344_x'
,'345_x','346_x','347_x','348_x','349_x','350_x','351_x','352_x','353_x','354_x','355_x','356_x','
357_x','358_x','359_x','360_x','361_x','362_x','363_x','364_x','365_x','366_x','367_x','368_x','36
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',
'27_y','28_y','29_y','30_y','31_y','32_y','33_y','34_y','35_y','36_y','37_y','38_y','39_y','40_y','
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
0_y','111_y','112_y','113_y','114_y','115_y','116_y','117_y','118_y','119_y','120_y','121_y','122_
y','123_y','124_y','125_y','126_y','127_y','128_y','129_y','130_y','131_y','132_y','133_y','134_y'
,'135_y','136_y','137_y','138_y','139_y','140_y','141_y','142_y','143_y','144_y','145_y','146_y','
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'
,'184_y','185_y','186_y','187_y','188_y','189_y','190_y','191_y','192_y','193_y','194_y','195_y','
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
```

In [0]:

```
#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 [0]:

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

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

In [0]:

```
# 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 [0]:

```
# 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 [0]:

```
data.head()
```

Out[0]:

	cwc_min	cwc_max	csc_min	csc_max	ctc_min	ctc_ma
1	0.199996000079998	0.166663888935184	0.0	0.0	0.14285510206997	0.099999000009999
2	0.399992000159997	0.399992000159997	0.499987500312492	0.499987500312492	0.444439506227709	0.444439506227709
3	0.833319444675922	0.714275510349852	0.999983333611106	0.857130612419823	0.687495703151855	0.687495703151855
4	0.0	0.0	0.599988000239995	0.499991666805553	0.249997916684028	0.230767455634957
5	0.749981250468738	0.749981250468738	0.499987500312492	0.499987500312492	0.624992187597655	0.624992187597655

5 rows � 794 columns

4.2 Converting strings to numerics

In [0]:

```
# 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
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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))
```

Featurizing text data with Tfidf W2V

In [2]:

```
# 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 [3]:

```
df.head()
```

Out[3]:

	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 [4]:

```
#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")
```

Joining Advanced and Basic Features

In [5]:

```
df1 = dfnlp.drop(['qid1','qid2','question1','question2','is_duplicate'],axis=1)
df2 = dfppro.drop(['qid1','qid2','question1','question2','is_duplicate'],axis=1)
df3 = df.drop(['qid1','qid2','question1','question2','is_duplicate'],axis=1)
```

In [6]:

```
# dataframe of nlp features
df1.head()
```

Out[6]:

	id	cwc_min	cwc_max	csc_min	csc_max	ctc_min	ctc_max	last_word_eq	first_word_eq	abs_len_diff	mean_len	tok
0	0	0.999980	0.833319	0.999983	0.999983	0.916659	0.785709	0.0	1.0	2.0	13.0	10
1	1	0.799984	0.399996	0.749981	0.599988	0.699993	0.466664	0.0	1.0	5.0	12.5	86
2	2	0.399992	0.333328	0.399992	0.249997	0.399996	0.285712	0.0	1.0	4.0	12.0	66
3	3	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.0	0.0	2.0	12.0	36
4	4	0.399992	0.199998	0.999950	0.666644	0.571420	0.307690	0.0	1.0	6.0	10.0	67

In [7]:

```
# data before preprocessing
df2.head()
```

Out[7]:

	id	freq_qid1	freq_qid2	q1len	q2len	q1_n_words	q2_n_words	word_Common	word_Total	word_share	freq_q1+q2	f
0	0	1	1	66	57	14	12	10.0	23.0	0.434783	2	0
1	1	4	1	51	88	8	13	4.0	20.0	0.200000	5	3
2	2	1	1	73	59	14	10	4.0	24.0	0.166667	2	0
3	3	1	1	50	65	11	9	0.0	19.0	0.000000	2	0
4	4	3	1	76	39	13	7	2.0	20.0	0.100000	4	2

In [8]:

```
df1  = df1.merge(df2, on='id',how='left')
```

In [9]:

```
df1.head(2)
```

Out[9]:

	id	cwc_min	cwc_max	csc_min	csc_max	ctc_min	ctc_max	last_word_eq	first_word_eq	abs_len_diff	...	freq_qid2
0	0	0.999980	0.833319	0.999983	0.999983	0.916659	0.785709	0.0	1.0	2.0	...	1
1	1	0.799984	0.399996	0.749981	0.599988	0.699993	0.466664	0.0	1.0	5.0	...	1

2 rows × 27 columns

Final Merged Matrix

In [10]:

```
df  = df.merge(df1, on='id',how='left')
```

In [11]:

```
df.head(2)
```

Out[11]:

	id	qid1	qid2	question1	question2	is_duplicate	cwc_min	cwc_max	csc_min	csc_max	...	freq_qid2	q1len	q2len	q
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	1
1	1	3	4	What is the story of Kohinoor (Koh-i-	What would happen if the Indian government	0	0.799984	0.399996	0.749981	0.599988	...	1	51	88	8

	id	qid1	qid2	(Koh-i-Noor) Dia... question1	government sto... question2	is_duplicate	cwc_min	cwc_max	csc_min	csc_max	...	freq_qid2	q1len	q2len	q

2 rows × 32 columns

In [12]:

```
df.to_csv('final_features_tfudf_w2v.csv')
```

4.3 Random train test split(70:30)

In [13]:

```
y_true = df['is_duplicate']
data = df.drop(['is_duplicate'],axis = 1)
from sklearn.model_selection import train_test_split
# split the data into test and train by maintaining same distribution of output varaible 'y_true'
[stratify=y_true]
X_train, X_test, y_train, y_test = train_test_split(data, y_true, stratify=y_true, test_size=0.2)
```

In [14]:

```
data.head(2)
```

Out[14]:

	id	qid1	qid2	question1	question2	cwc_min	cwc_max	csc_min	csc_max	ctc_min	...	freq_qid2	q1len	q2len	q1_n
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...	0.999980	0.833319	0.999983	0.999983	0.916659	...	1	66	57	14
1	1	3	4	What is the story of Kohinoor (Koh-i-Noor) Dia...	What would happen if the Indian government sto...	0.799984	0.399996	0.749981	0.599988	0.699993	...	1	51	88	8

2 rows × 31 columns

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 : (323432, 31)
Number of data points in test data : (80858, 31)
```

In [0]:

```
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 train 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:  0.6324857142857143 Class 1:  0.36751428571428574
---------- Distribution of output variable in train data ----------
Class 0:  0.3675 Class 1:  0.3675
```

In [101]:

```
# 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()
```

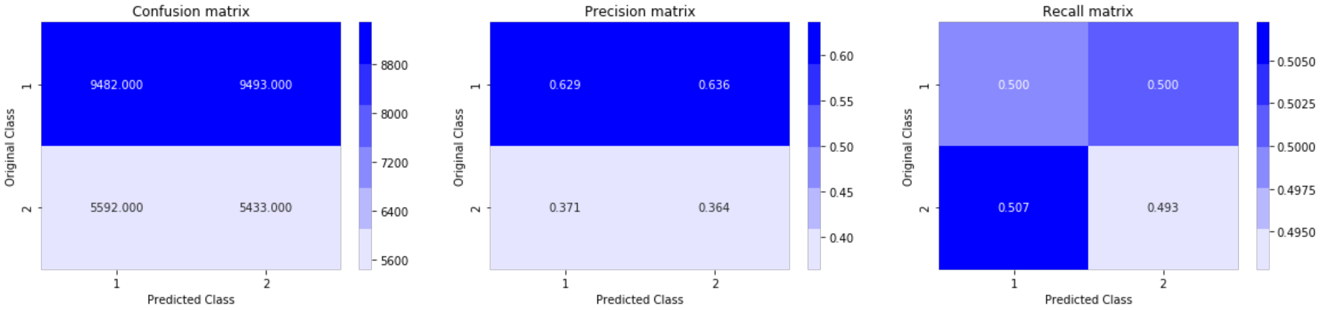
4.4 Building a random model (Finding worst-case log-loss)

In [0]:

```
# 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 0.887242646958
```



TFIDF-W2V Vectorization

Train Data

In [16]:

```
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.feature_extraction.text import CountVectorizer
# merge texts
questions = list(X_train['question1']) + list(X_train['question2'])

tfidf = TfidfVectorizer(lowercase=False, )
tfidf.fit_transform(questions)

# dict key:word and value:tf-idf score
word2tfidf = dict(zip(tfidf.get_feature_names(), tfidf.idf_))
```

In [17]:

```
from tqdm import tqdm
```

In [ ]:

```
# en_vectors_web_lg, which includes over 1 million unique vectors.
nlp = spacy.load('en_core_web_sm')

vecs1 = []
# https://github.com/noamraph/tqdm
# tqdm is used to print the progress bar
for qu1 in tqdm(list(X_train['question1'])):
    doc1 = nlp(qu1)
    # 384 is the number of dimensions of vectors
    mean_vec1 = np.zeros([len(doc1) , len(doc1[0].vector)])
    for word1 in doc1:
        # word2vec
        vec1 = word1.vector
        # fetch df score
        try:
            idf = word2tfidf[str(word1)]
        except:
            idf = 0
        # compute final vec
        mean_vec1 += vec1 * idf
    mean_vec1 = mean_vec1.mean(axis=0)
    vecs1.append(mean_vec1)
```

In [20]:

```
X_train['q1_feats_m'] = list(vecs1)
```

In [22]:

```
# en_vectors_web_lg, which includes over 1 million unique vectors.
nlp = spacy.load('en_core_web_sm')

vecs1 = []
# https://github.com/noamraph/tqdm
# tqdm is used to print the progress bar
for qu1 in tqdm(list(X_train['question2'])):
    doc1 = nlp(qu1)
    # 384 is the number of dimensions of vectors
    mean_vec1 = np.zeros([len(doc1) , len(doc1[0].vector)])
    for word1 in doc1:
        # word2vec
        vec1 = word1.vector
        # fetch df score
        try:
            idf = word2tfidf[str(word1)]
        except:
            idf = 0
        # compute final vec
        mean_vec1 += vec1 * idf
    mean_vec1 = mean_vec1.mean(axis=0)
    vecs1.append(mean_vec1)
X_train['q2_feats_m'] = list(vecs1)
```

```
100%|██████████████████████████████████| 323432/323432 [1:05:48<00:00, 81.92it/s]
```

Test Data

In [23]:

```
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.feature_extraction.text import CountVectorizer
# merge texts
questions = list(X_test['question1']) + list(X_test['question2'])

tfidf = TfidfVectorizer(lowercase=False, )
tfidf.fit_transform(questions)

# dict key:word and value:tf-idf score
word2tfidf = dict(zip(tfidf.get_feature_names(), tfidf.idf_))
```

In [24]:

```
# en_vectors_web_lg, which includes over 1 million unique vectors.
nlp = spacy.load('en_core_web_sm')

vecs1 = []
# https://github.com/noamraph/tqdm
# tqdm is used to print the progress bar
for qu1 in tqdm(list(X_test['question1'])):
    doc1 = nlp(qu1)
    # 384 is the number of dimensions of vectors
    mean_vec1 = np.zeros([len(doc1),len(doc1[0].vector)])
    for word1 in doc1:
        # word2vec
        vec1 = word1.vector
        # fetch df score
        try:
            idf = word2tfidf[str(word1)]
        except:
            idf = 0
        # compute final vec
        mean_vec1 += vec1 * idf
    mean_vec1 = mean_vec1.mean(axis=0)
    vecs1.append(mean_vec1)
X_test['q1_feats_n'] = list(vecs1)
```

```
100%|████████████████████████████████████████| 80858/80858 [16:28<00:00, 81.79it/s]
```

In [25]:

```
# en_vectors_web_lg, which includes over 1 million unique vectors.
nlp = spacy.load('en_core_web_sm')

vecs1 = []
# https://github.com/noamraph/tqdm
# tqdm is used to print the progress bar
for qu1 in tqdm(list(X_test['question2'])):
    doc1 = nlp(qu1)
    # 384 is the number of dimensions of vectors
    mean_vec1 = np.zeros([len(doc1), len(doc1[0].vector)])
    for word1 in doc1:
        # word2vec
        vec1 = word1.vector
        # fetch df score
        try:
            idf = word2tfidf[str(word1)]
        except:
            idf = 0
        # compute final vec
        mean_vec1 += vec1 * idf
    mean_vec1 = mean_vec1.mean(axis=0)
    vecs1.append(mean_vec1)
X_test['q2_feats_n'] = list(vecs1)
```

```
100%|████████████████████████████████████████| 80858/80858 [16:38<00:00, 80.27it/s]
```

Convert list to Dataframes

To Avoid

- ValueError: setting an array element with a sequence

For Train Data

In [42]:

```
id=X_train.index
```

In [45]:

```
df5_q1 = pd.DataFrame(X_train.q1_feats_m.values.tolist(), index= id)
```

In [46]:

```
df5_q2= pd.DataFrame(X_train.q2_feats_m.values.tolist(), index= id)
```

In [50]:

```
df5_q1.head(2)
```

Out[50]:

	0	1	2	3	4	5	6	7	8	
2548	143.945724	-120.000482	-140.590737	-91.522927	-120.897109	-51.280953	178.984797	82.253759	33.858073	198.91
33679	174.828672	-149.067384	-129.059881	-212.669318	-138.425195	28.927610	349.465953	173.819329	-109.216085	71.762

2 rows × 96 columns

In [51]:

```
df5_q2.head(2)
```

Out[51]:

	0	1	2	3	4	5	6	7	8	
2548	107.018199	-40.731070	-116.605322	-148.561504	-69.916028	100.063720	225.440581	207.041259	-21.185057	152.8192
33679	149.185010	-70.686288	-28.787829	-143.816908	41.441735	56.237627	146.584699	31.551151	-21.275532	189.2188

2 rows × 96 columns

In [54]:

```
df5_q1['id']=X_train['id']
```

In [55]:

```
df5_q2['id']=X_train['id']
```

In [56]:

```
df6_q1['id']=X_test['id']
```

In [57]:

```
df6_q2['id']=X_test['id']
```

For Test Data

In [47]:

```
id1=X_test.index
```

In [48]:

```
df6_q1 = pd.DataFrame(X_test.q1_feats_n.values.tolist(), index= id1)
```

In [49]:

```
df6_q2 = pd.DataFrame(X_test.q2_feats_n.values.tolist(), index= id1)
```

In [52]:

```
df6_q1.head(2)
```

Out[52]:

	0	1	2	3	4	5	6	7	8	9	..
79928	38.089639	-70.407112	-42.475735	-36.504209	-3.362599	-23.014704	133.568992	79.162429	-44.185755	75.725960	..
63729	144.390222	-118.603944	25.062115	-73.217542	-7.708087	-27.166609	55.116142	33.640604	-35.889599	129.379518	..

2 rows × 96 columns

In [53]:

In [53]:

```
df6_q2.head(2)
```

Out[53]:

	0	1	2	3	4	5	6	7	8	9	...
79928	45.340331	-61.047595	-34.908880	-22.600308	-7.940771	-21.427804	89.124615	72.912591	-24.295014	67.933343	...
63729	65.830641	-74.018202	21.786562	-32.019285	-20.319113	27.370222	36.471790	9.259570	-26.280582	109.903012	...

2 rows × 96 columns

Perform all merging operations on 'id'

In [58]:

```
df_f1=df5_q1.merge(df5_q2,on='id',how='left')
```

In [59]:

```
df_f2=df6_q1.merge(df6_q2,on='id',how='left')
```

In [61]:

```
X_train=X_train.merge(df_f1,on='id',how='left')
```

In [62]:

```
X_test=X_test.merge(df_f2,on='id',how='left')
```

Drop unwanted columns

In [63]:

```
X_train= X_train.drop(['q1_feats_m','q2_feats_m'],axis=1)
```

In [64]:

```
X_test= X_test.drop(['q1_feats_n','q2_feats_n'],axis=1)
```

In [87]:

```
X_train= X_train.drop(['question1','question2'],axis=1)
X_train= X_train.drop(['qid1','qid2'],axis=1)
```

In [88]:

```
X_train.head(2)
```

Out[88]:

	id	cwc_min	cwc_max	csc_min	csc_max	ctc_min	ctc_max	last_word_eq	first_word_eq	abs_len_diff	...	86
0	2548	0.799984	0.666656	0.999975	0.57142	0.888879	0.61538	0.0	1.0	4.0	...	90.383
1	33679	0.000000	0.000000	0.000000	0.00000	0.000000	0.00000	0.0	0.0	8.0	...	22.213

2 rows × 219 columns

In [90]:

```
X_test= X_test.drop(['question1','question2'],axis=1)
X_test= X_test.drop(['qid1','qid2'],axis=1)
```

In [91]:

```
X_test.head(2)
```

Out[91]:

	id	cwc_min	cwc_max	csc_min	csc_max	ctc_min	ctc_max	last_word_eq	first_word_eq	abs_len_diff	...	86
0	79928	0.999967	0.749981	0.99998	0.999980	0.999988	0.888879	0.0	1.0	1.0	...	63.0851
1	63729	0.999967	0.749981	0.99998	0.833319	0.888879	0.799992	1.0	1.0	1.0	...	29.6849

2 rows × 219 columns

In [92]:

```
X_train.columns
```

Out[92]:

```
Index(['id', 'cwc_min', 'cwc_max', 'csc_min', 'csc_max', 'ctc_min', 'ctc_max',
       'last_word_eq', 'first_word_eq', 'abs_len_diff',
       ...
       '86_y', '87_y', '88_y', '89_y', '90_y', '91_y', '92_y', '93_y', '94_y',
       '95_y'],
      dtype='object', length=219)
```

In [93]:

```
X_train.shape
```

Out[93]:

```
(323432, 219)
```

In [94]:

```
y_train.shape
```

Out[94]:

```
(323432,)
```

In [95]:

```
X_test.columns
```

Out[95]:

```
Index(['id', 'cwc_min', 'cwc_max', 'csc_min', 'csc_max', 'ctc_min', 'ctc_max',
       'last_word_eq', 'first_word_eq', 'abs_len_diff',
       ...
       '86_y', '87_y', '88_y', '89_y', '90_y', '91_y', '92_y', '93_y', '94_y',
       '95_y'],
      dtype='object', length=219)
```

In [96]:

```
X_test.shape
```

Out[96]:

```
(80858, 219)
```

In [97]:

```
y_test.shape
```

Out[97]:

```
(80858,)
```

In [98]:

```
nan_rows = X_train[X_train.isnull().any(1)]
print (nan_rows)
```

```
Empty DataFrame
Columns: [id, cwc_min, cwc_max, csc_min, csc_max, ctc_min, ctc_max, last_word_eq, first_word_eq, a
bs_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, wor
d_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, 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, 43_
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_x, 58_x, 59_x,
60_x, 61_x, 62_x, 63_x, 64_x, 65_x, 66_x, 67_x, 68_x, 69_x, 70_x, 71_x, 72_x, ...]
Index: []

[0 rows x 219 columns]
```

In [99]:

```
nan_rows = X_test[X_test.isnull().any(1)]
print (nan_rows)
```

```
Empty DataFrame
Columns: [id, cwc_min, cwc_max, csc_min, csc_max, ctc_min, ctc_max, last_word_eq, first_word_eq, a
bs_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, wor
d_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, 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, 43_
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_x, 58_x, 59_x,
60_x, 61_x, 62_x, 63_x, 64_x, 65_x, 66_x, 67_x, 68_x, 69_x, 70_x, 71_x, 72_x, ...]
Index: []

[0 rows x 219 columns]
```

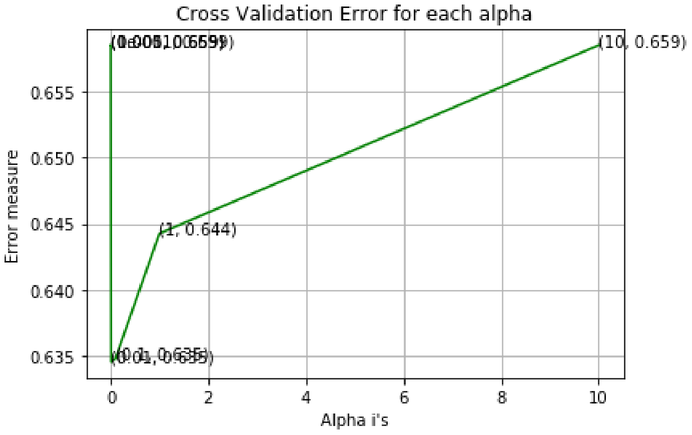
4.4 Logistic Regression with hyperparameter tuning

In [107]:

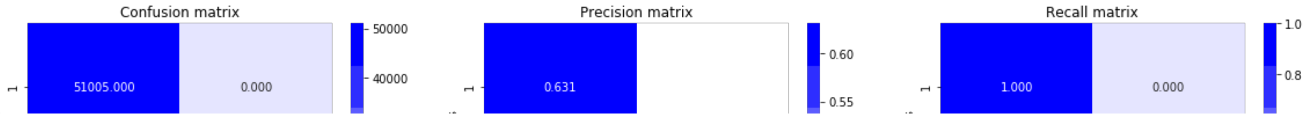
```
alpha = [10 ** x for x in range(-5, 2)] # hyperparam for SGD classifier.

# 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:
```

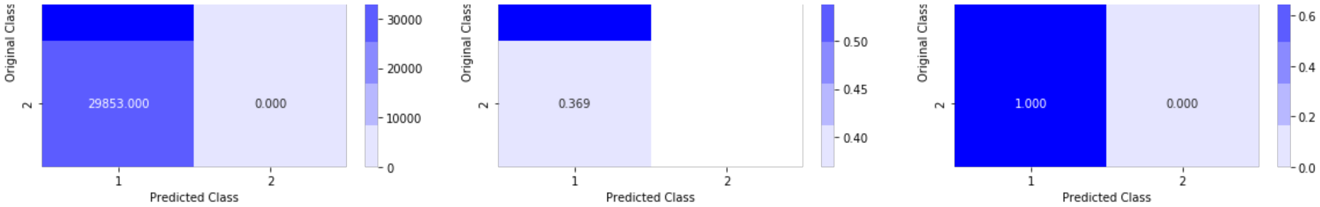
```
#------------------------------


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.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, 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: 0.6585300338401181
For values of alpha =  0.0001 The log loss is: 0.6585300338401181
For values of alpha =  0.001 The log loss is: 0.6585300338401181
For values of alpha =  0.01 The log loss is: 0.6345103862505338
For values of alpha =  0.1 The log loss is: 0.6347553310586057
For values of alpha =  1 The log loss is: 0.644249829236438
For values of alpha =  10 The log loss is: 0.6585300338401181
```



```
For values of best alpha =  0.01 The train log loss is: 0.6339300806203315
For values of best alpha =  0.01 The test log loss is: 0.6345103862505338
Total number of data points : 80858
```



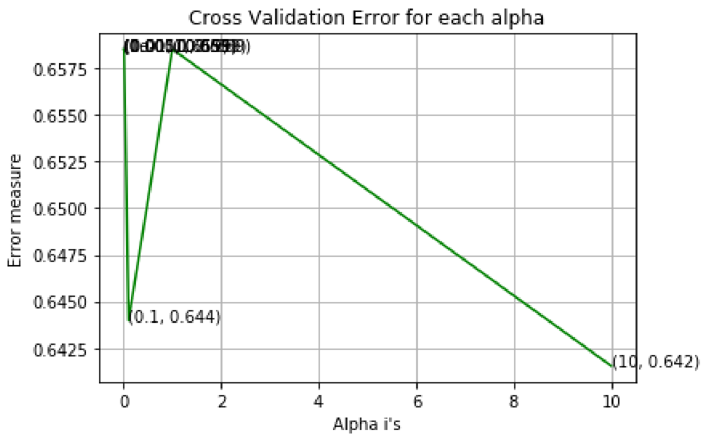


4.5 Linear SVM with hyperparameter tuning

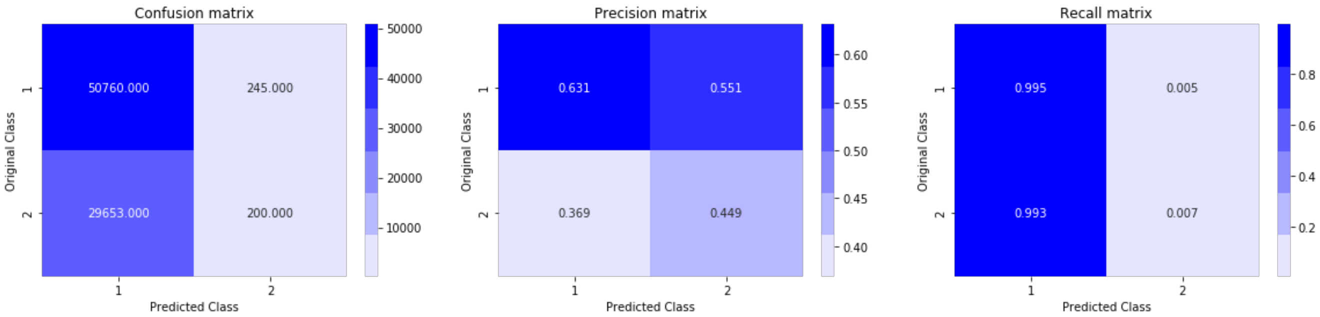
In [103]:

```
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: 0.6585300338401181
For values of alpha =  0.0001 The log loss is: 0.6585300338401181
For values of alpha =  0.001 The log loss is: 0.6585300338401181
For values of alpha =  0.01 The log loss is: 0.6585300338401181
For values of alpha =  0.1 The log loss is: 0.6439695396600468
For values of alpha =  1 The log loss is: 0.6585300338401181
For values of alpha =  10 The log loss is: 0.6415361070102844
```



```
For values of best alpha =  10 The train log loss is: 0.6407171093172486
For values of best alpha =  10 The test log loss is: 0.6415361070102844
Total number of data points : 80858
```



4.6 XGBoost

In [104]:

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

d_train = xgb.DMatrix(X_train, label=y_train)
d_test = xgb.DMatrix(X_test, label=y_test)

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

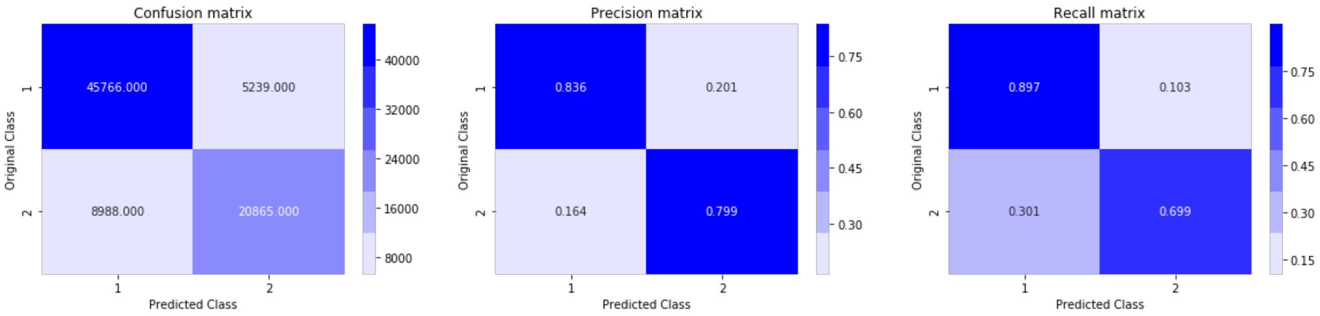
```
[0] train-logloss:0.684818 valid-logloss:0.684836
Multiple eval metrics have been passed: 'valid-logloss' will be used for early stopping.

Will train until valid-logloss hasn't improved in 20 rounds.
[10] train-logloss:0.615305 valid-logloss:0.61506
[20] train-logloss:0.564408 valid-logloss:0.56401
[30] train-logloss:0.526451 valid-logloss:0.525967
[40] train-logloss:0.497395 valid-logloss:0.496859
[50] train-logloss:0.474469 valid-logloss:0.473915
[60] train-logloss:0.456198 valid-logloss:0.455621
[70] train-logloss:0.441563 valid-logloss:0.440069
```

```
[70] train-logloss:0.441563 valid-logloss:0.440962
[80] train-logloss:0.429767 valid-logloss:0.429218
[90] train-logloss:0.420163 valid-logloss:0.419599
[100] train-logloss:0.412267 valid-logloss:0.411694
[110] train-logloss:0.405503 valid-logloss:0.404959
[120] train-logloss:0.399896 valid-logloss:0.39933
[130] train-logloss:0.395173 valid-logloss:0.394609
[140] train-logloss:0.391341 valid-logloss:0.390714
[150] train-logloss:0.387835 valid-logloss:0.387264
[160] train-logloss:0.384884 valid-logloss:0.38432
[170] train-logloss:0.382321 valid-logloss:0.381816
[180] train-logloss:0.379867 valid-logloss:0.379446
[190] train-logloss:0.377635 valid-logloss:0.377215
[200] train-logloss:0.375796 valid-logloss:0.375413
[210] train-logloss:0.373946 valid-logloss:0.373634
[220] train-logloss:0.372236 valid-logloss:0.372
[230] train-logloss:0.370855 valid-logloss:0.370651
[240] train-logloss:0.369052 valid-logloss:0.368935
[250] train-logloss:0.367803 valid-logloss:0.367691
[260] train-logloss:0.366555 valid-logloss:0.366493
[270] train-logloss:0.365114 valid-logloss:0.365107
[280] train-logloss:0.363917 valid-logloss:0.36395
[290] train-logloss:0.362793 valid-logloss:0.362826
[300] train-logloss:0.36176 valid-logloss:0.361803
[310] train-logloss:0.360724 valid-logloss:0.360814
[320] train-logloss:0.359675 valid-logloss:0.359776
[330] train-logloss:0.358678 valid-logloss:0.358799
[340] train-logloss:0.357711 valid-logloss:0.357866
[350] train-logloss:0.356788 valid-logloss:0.356992
[360] train-logloss:0.355946 valid-logloss:0.356173
[370] train-logloss:0.355093 valid-logloss:0.355355
[380] train-logloss:0.354312 valid-logloss:0.354615
[390] train-logloss:0.353442 valid-logloss:0.353797
[399] train-logloss:0.352629 valid-logloss:0.35304
The test log loss is: 0.3530387531080572
```

In [105]:

```
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 : 80858
```



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.

Featurizing text data with Tfidf word-vectors

In [67]:

```
import pandas as pd
import matplotlib.pyplot as plt
import re
import time
import warnings
import numpy as np
from nltk.corpus import stopwords
from sklearn.preprocessing import normalize
from sklearn.feature_extraction.text import CountVectorizer
from sklearn.feature_extraction.text import TfidfVectorizer
warnings.filterwarnings("ignore")
import sys
import os
import pandas as pd
import numpy as np
from tqdm import tqdm

# exctract word2vec vectors
# https://github.com/explosion/spaCy/issues/1721
# http://landinghub.visualstudio.com/visual-cpp-build-tools
import spacy
os.chdir('C:/Users/kingsubham27091995/Desktop/AppliedAiCouse/CASE
STUDIES/QuoraQuestionPairSimilarity/Quora')
```

In [68]:

```
# 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 [69]:

```
df.head()
```

Out[69]:

	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 [70]:

```
df.shape
```

Out[70]:

```
(404290, 6)
```

In [81]:

```
#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 [92]:

```
df1 = dfnlp.drop(['qid1','qid2','question1','question2','is_duplicate'],axis=1)
df2 = dfppro.drop(['qid1','qid2','question1','question2','is_duplicate'],axis=1)
df3 = df.drop(['qid1','qid2','question1','question2','is_duplicate'],axis=1)
```

In [93]:

```
df1.head(2)
```

Out[93]:

	id	cwc_min	cwc_max	csc_min	csc_max	ctc_min	ctc_max	last_word_eq	first_word_eq	abs_len_diff	mean_len	tok
0	0	0.999980	0.833319	0.999983	0.999983	0.916659	0.785709	0.0	1.0	2.0	13.0	10(
1	1	0.799984	0.399996	0.749981	0.599988	0.699993	0.466664	0.0	1.0	5.0	12.5	86

In [84]:

```
df2.head(2)
```

Out[84]:

	id	freq_qid1	freq_qid2	q1len	q2len	q1_n_words	q2_n_words	word_Common	word_Total	word_share	freq_q1+q2	f
0	0	1	1	66	57	14	12	10.0	23.0	0.434783	2	(
1	1	4	1	51	88	8	13	4.0	20.0	0.200000	5	3

In [86]:

```
df3.head(2)
```

Out[86]:

	id
0	0
1	1

In [94]:

```
df1  = df1.merge(df2, on='id',how='left')
```

In [95]:

```
df1.head(2)
```

Out[95]:

	id	cwc_min	cwc_max	csc_min	csc_max	ctc_min	ctc_max	last_word_eq	first_word_eq	abs_len_diff	...	freq_qid2
0	0	0.999980	0.833319	0.999983	0.999983	0.916659	0.785709	0.0	1.0	2.0	...	1
1	1	0.799984	0.399996	0.749981	0.599988	0.699993	0.466664	0.0	1.0	5.0	...	1

2 rows � 27 columns

Check for NaN Rows

In [127]:

```
nan_rows = df1[df1.isnull().any(1)]
print (nan_rows)
```

```
Empty DataFrame
Columns: [id, cwc_min, cwc_max, csc_min, csc_max, ctc_min, ctc_max, last_word_eq, first_word_eq, a
bs_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, wor
d_Total, word_share, freq_q1+q2, freq_q1-q2]
Index: []

[0 rows x 27 columns]
```

Final merged matrix

In [96]:

```
df  = df.merge(df1, on='id',how='left')
```

In [97]:

```
df.head(2)
```

Out[97]:

	id	qid1	qid2	question1	question2	is_duplicate	cwc_min	cwc_max	csc_min	csc_max	...	freq_qid2	q1len	q2len	q
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	1
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	8

2 rows � 32 columns

In [98]:

```
df.to_csv('final_features.csv')
```

Random splitting the data

In [99]:

```
y_true = df['is_duplicate']
data = df.drop(['is_duplicate'],axis = 1)
from sklearn.model_selection import train_test_split
# split the data into test and train by maintaining same distribution of output varaible 'y_true'
[stratify=y_true]
X_train, X_test, y_train, y_test = train_test_split(data, y_true, stratify=y_true, test_size=0.2)
```

In [100]:

```
data.head(2)
```

Out[100]:

	id	qid1	qid2	question1	question2	cwc_min	cwc_max	csc_min	csc_max	ctc_min	...	freq_qid2	q1len	q2len	q1_n
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...	0.999980	0.833319	0.999983	0.999983	0.916659	...	1	66	57	14
1	1	3	4	What is the story of Kohinoor (Koh-i-Noor) Dia...	What would happen if the Indian government sto...	0.799984	0.399996	0.749981	0.599988	0.699993	...	1	51	88	8

2 rows � 31 columns

In [101]:

```
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 : (323432, 31)
Number of data points in test data : (80858, 31)
```

Distribution of Yi's

In [102]:

```
from collections import Counter
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 train 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:  0.6308033837097133 Class 1:  0.36919661629028666
---------- Distribution of output variable in train data ----------
Class 0:  0.36920279997031835 Class 1:  0.36920279997031835
```

Confusion Matrix

In [103]:

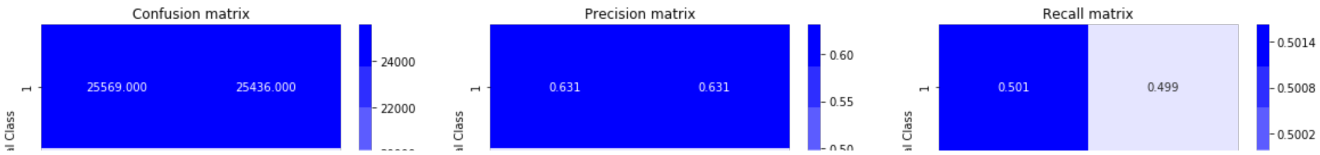
```
# This function plots the confusion matrices given y_i, y_i_hat.
def plot_confusion_matrix(test_y, predict_y):
    C = confusion_matrix(test_y, predict_y)
    # C = 9,9 matrix, each cell (i,j) represents number of points of class i are predicted class j

    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],
    # 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()
```

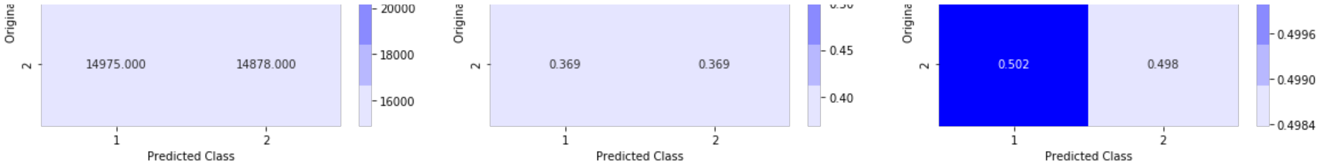
Building a random model (Finding worst-case log-loss)

In [78]:

```
# 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 0.8871416649174547
```





- Random Model has a log-loss= 88.7%

TFIDF Vectorization

In [113]:

```
tfidf = TfidfVectorizer(min_df = 3,ngram_range = (1,4),lowercase = False)
train_questions = X_train['question1'] + X_train['question2']
tfidf_train_feature = tfidf.fit_transform(train_questions)
train_X = normalize(tfidf_train_feature,axis = 0)

te_questions = X_test['question1'] + X_test['question2']
tfidf_test_feature = tfidf.transform(te_questions)
test_X = normalize(tfidf_test_feature,axis = 0)
```

In [114]:

```
train_X.shape
```

Out[114]:

```
(323432, 872697)
```

In [116]:

```
y_train.shape
```

Out[116]:

```
(323432,)
```

In [115]:

```
test_X.shape
```

Out[115]:

```
(80858, 872697)
```

In [109]:

```
y_test.shape
```

Out[109]:

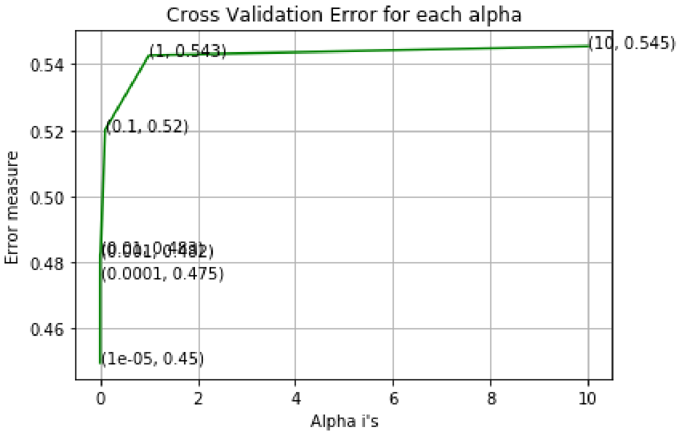
```
(80858,)
```

Logistic Regression with hyperparameter tuning

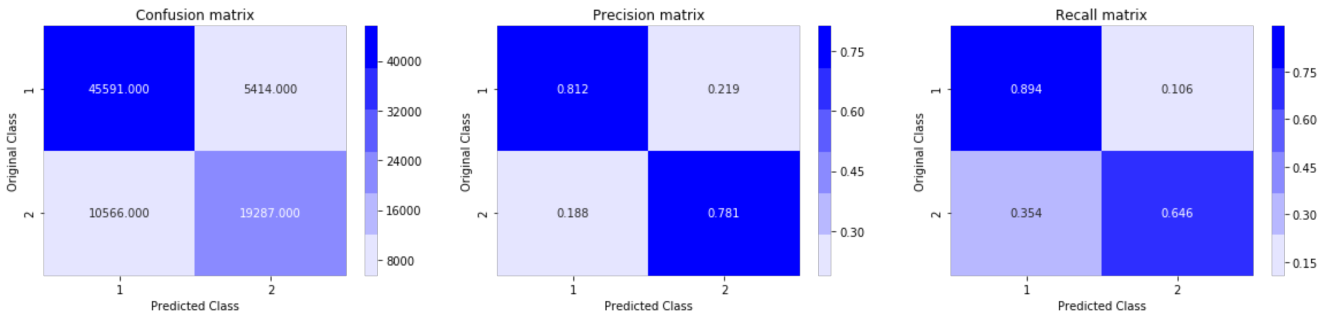
In [117]:

```
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
# 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.


log_error_array=[]
for i in alpha:
    clf = SGDClassifier(alpha=i, penalty='l2', loss='log', random_state=42)
    clf.fit(train_X, y_train)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(train_X, y_train)
    predict_y = sig_clf.predict_proba(test_X)
    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='l2', loss='log', random_state=42)
clf.fit(train_X, y_train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(train_X, y_train)

predict_y = sig_clf.predict_proba(train_X)
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(test_X)
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: 0.4495980702093683
For values of alpha =  0.0001 The log loss is: 0.4751914587895215
For values of alpha =  0.001 The log loss is: 0.48223553187352447
For values of alpha =  0.01 The log loss is: 0.48309568406578707
For values of alpha =  0.1 The log loss is: 0.5201027337838955
For values of alpha =  1 The log loss is: 0.5426655384904204
For values of alpha =  10 The log loss is: 0.5454150951529114
```



```
For values of best alpha =  1e-05 The train log loss is: 0.2729361317869527
For values of best alpha =  1e-05 The test log loss is: 0.4495980702093683
Total number of data points : 80858
```

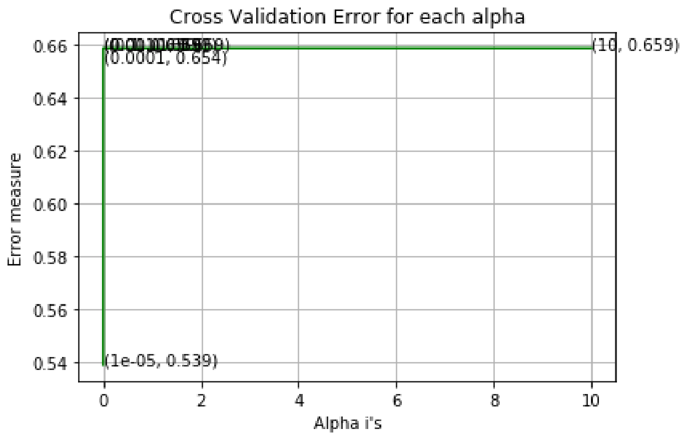


Linear SVM with hyperparameter tuning

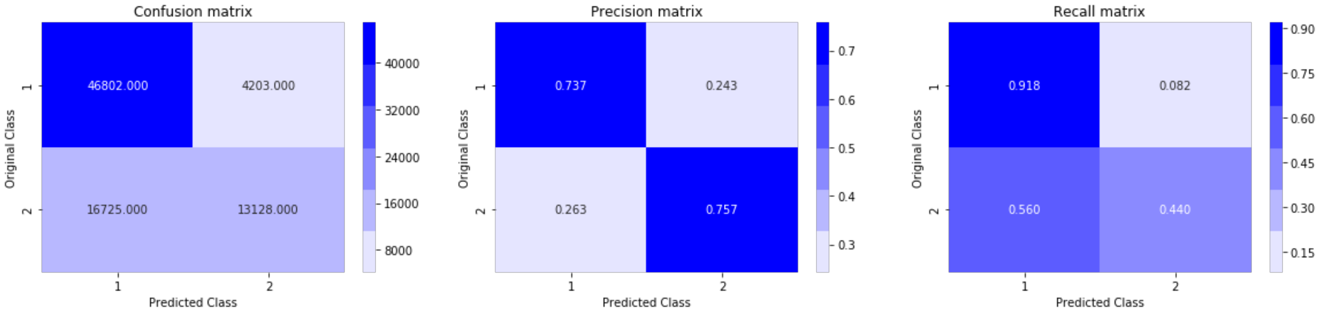
In [118]:

```
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.



log_error_array=[]
for i in alpha:
    clf = SGDClassifier(alpha=i, penalty='l1', loss='hinge', random_state=42)
    clf.fit(train_X, y_train)
    sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
    sig_clf.fit(train_X, y_train)
    predict_y = sig_clf.predict_proba(test_X)
    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(train_X, y_train)
sig_clf = CalibratedClassifierCV(clf, method="sigmoid")
sig_clf.fit(train_X, y_train)

predict_y = sig_clf.predict_proba(train_X)
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(test_X)
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: 0.5390222178496857
For values of alpha =  0.0001 The log loss is: 0.6536423396516227
For values of alpha =  0.001 The log loss is: 0.6585300338919
For values of alpha =  0.01 The log loss is: 0.6585300338918998
For values of alpha =  0.1 The log loss is: 0.6585300338917621
For values of alpha =  1 The log loss is: 0.6585300338918154
For values of alpha =  10 The log loss is: 0.6585300338918296
```



```
For values of best alpha =  1e-05 The train log loss is: 0.5233701413863716
For values of best alpha =  1e-05 The test log loss is: 0.5390222178496857
Total number of data points : 80858
```



XGBoost

In [120]:

```
import scipy.stats as sc
import xgboost as xgb
from sklearn.model_selection import RandomizedSearchCV
params = {"learning_rate":sc.uniform(0.02,0.1),
             "n_estimators":sc.randint(10,250),
             "max_depth":sc.randint(6,10),
             "min_child_weight":sc.randint(3,10),

        }
xgb_classifier = xgb.XGBClassifier(objective = 'binary:logistic')
grid = RandomizedSearchCV(xgb_classifier, params, cv = 3, scoring = "log_loss", verbose = 1, random
_state = 0)
grid.fit(train_X,y_train)
print(grid.best_params_)
```

```
Fitting 3 folds for each of 10 candidates, totalling 30 fits
```

```
[Parallel(n_jobs=1)]: Done  30 out of  30 | elapsed: 1147.9min finished
```

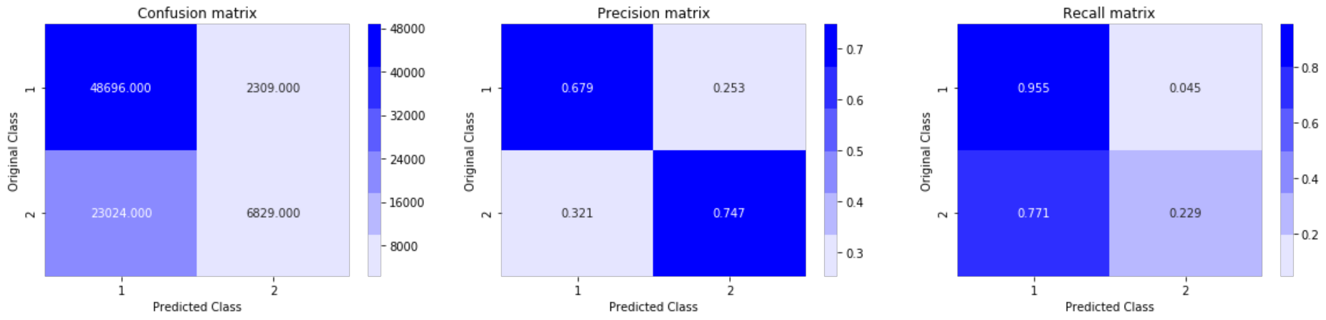
```
{'learning_rate': 0.10579456176227568, 'max_depth': 9, 'min_child_weight': 4, 'n_estimators': 221}
```

In [125]:

```
predict_y = grid.predict_proba(train_X)
```

```
print("The train log loss is:",log_loss(y_train, predict_y, eps=1e-15))
predict_y = grid.predict_proba(test_X)
print("/n The test log loss is:",log_loss(y_test, predict_y, eps=1e-15))
predicted_y =np.argmax(predict_y,axis=1)
print("/n Total number of data points :", len(predicted_y))
plot_confusion_matrix(y_test, predicted_y)
```

```
The train log loss is: 0.43943893697720976
/n The test log loss is: 0.582029302762652
/n Total number of data points : 80858
```



In [106]:

```
from prettytable import PrettyTable
ptable = PrettyTable()
ptable.title = " Model Comparision "
ptable.field_names = ['Serial No.', 'Model Name', 'Tokenizer','Hyperparameter Tunning', 'Test Log L
oss']
ptable.add_row(["1","Random","TFIDF Weighted W2V","NA","0.89"])
ptable.add_row(["2","Logistic Regression","TFIDF Weighted W2V","Done","0.6"])
ptable.add_row(["3","Linear SVM","TFIDF Weighted W2V","Done","0.63"])
ptable.add_row(["4","XGBoost","TFIDF Weighted W2V","NA","0.35"])
ptable.add_row(["\n","\n","\n","\n","\n"])
ptable.add_row(["1","Random","TFIDF","NA","0.88"])
ptable.add_row(["2","Logistic Regression","TFIDF","Done","0.44"])
ptable.add_row(["3","Linear SVM","TFIDF","Done","0.539"])
ptable.add_row(["4","XGBoost","TFIDF","Done","0.582"])
print(ptable)
```

```
+------------+---------------------+--------------------+------------------------+---------------+
| Serial No. |      Model Name     |     Tokenizer      | Hyperparameter Tunning | Test Log Loss |
+------------+---------------------+--------------------+------------------------+---------------+
|     1      |        Random       | TFIDF Weighted W2V |           NA           |      0.89     |
|     2      | Logistic Regression | TFIDF Weighted W2V |          Done          |      0.6      |
|     3      |      Linear SVM     | TFIDF Weighted W2V |          Done          |      0.63     |
|     4      |       XGBoost       | TFIDF Weighted W2V |           NA           |      0.35     |
|            |                     |                    |                        |               |
|            |                     |                    |                        |               |
|     1      |        Random       |       TFIDF        |           NA           |      0.88     |
|     2      | Logistic Regression |       TFIDF        |          Done          |      0.44     |
|     3      |      Linear SVM     |       TFIDF        |          Done          |     0.539     |
|     4      |       XGBoost       |       TFIDF        |          Done          |     0.582     |
+------------+---------------------+--------------------+------------------------+---------------+
```

Conclusion:

As dimension increases Logistic Regression and Linear SVM starts to perform well,whereas XGBoost produces almost same results after hyperparameter tunning

We need to tune it using more number of parameters to get the best value..

How did I implement the model (Step wise explanation):

1. Firstly we preprocessed our data, created our dataframes, merged it and got out final matrix.
2. Then we Splitted out data randomly into 80:20 . It is better to split it based on Time, since the model could predict for future unseen data too. It would become a perfect Generalised model. But, there was no timestamp column provided, so the only option was to split it randomly.

option was to split it randomly.

3. Then we TFIDF Vectorised the Qustion text and merged it to our merged data matrix to get out Final Matrix which was now ready for Classification Task.
4. Now, we have applied simple Random/Dumb Model. It gave a log loss of 0.88. This is the worst case log-loss. Any model we design should have a log-loss lesser than this dumb model.
5. After that we have applied Logistic Regression and hyperparameter tuned it. It gave a log-loss of 0.44, which is significantly lower than Random Model. We can also see that there is no Overfitting problem , since, Train log-loss and Test log-loss and very close.
6. After that we have applied Linear SVM and hyperparameter tuned it. It gave the log-loss of 0.539,which is significantly lower than Random Model. We can also see that there is no Overfitting problem , since, Train log-loss and Test log-loss and very close.
7. After that we have applied XGBoost and hyperparameter tuned it. It gave the log-loss of 0.58,which is significantly lower than Random Model. We can also see that there is no Overfitting problem , since, Train log-loss and Test log-loss and very close.This gave a little bad result since due to using TFIDF the dimension increased dramatically , this XGBoost failed to give better results.
8. Finally for this case study, we conclude for low dimesion data prefer **hyperparameter tuned 'XGBoost' model** and for high dimension data prefer **either 'Linear SVM' or 'Logistic Regression'**