In [1]:
```
#import libraries....

import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import plotly.express as px
import folium

from sklearn.model_selection import train_test_split
from sklearn.metrics import log_loss,confusion_matrix,f1_score
from sklearn.neighbors import KNeighborsClassifier
from sklearn.linear_model import SGDClassifier,LogisticRegression
from sklearn.model_selection import RandomizedSearchCV
from sklearn.tree import DecisionTreeClassifier
from sklearn.calibration import CalibratedClassifierCV
from sklearn.naive_bayes import MultinomialNB,GaussianNB
import lightgbm as lgb
from sklearn.model_selection import StratifiedKFold
import xgboost as xgb
from mlxtend.classifier import StackingClassifier
from sklearn.preprocessing import Normalizer,MinMaxScaler,StandardScaler

import xgboost as xgb
from sklearn.ensemble import RandomForestClassifier
from sklearn.model_selection import RandomizedSearchCV
from sklearn.preprocessing import LabelEncoder



import datetime

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

Choosing metric

- From EDA part, It is sure that there is high class imbalance in the dataset. Also review_score 1,2,3 are very important, since misclassification of them would cause customer loss to the seller. So False positive should be the concern here.
- Here precision and recall of each class is important. Precision of class 4,5 is more important and recall of 1,2,3 class is very important. So we can use f1 score,which is a combination of precision and recall, Since each is important to us we can consider Macro f1 score..
- Based on this observation and business problem, I choose Macro F1 score as metric. Also I want to check multi-class confusion matrix, so that we can observe the misclassification easily.

Metric choosen,

*** Macro F1 score**
*** Multi-class Confusion matrix**

Multi class classification among 1,2,3,4

In [2]:
```
#load the data with all created features
data = pd.read_csv("data_with_advanced_features.csv")
data.drop("Unnamed: 0", inplace=True, axis=1)
```

In [3]:
```
data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 113105 entries, 0 to 113104
Data columns (total 71 columns):
 #   Column                          Non-Null Count   Dtype
---  ------                          --------------   -----
 0   order_id                        113105 non-null  object
 1   payment_sequential              113105 non-null  int64
 2   payment_type                    113105 non-null  object
 3   payment_installments            113105 non-null  int64
 4   payment_value                   113105 non-null  float64
 5   customer_id                     113105 non-null  object
 6   order_status                    113105 non-null  object
 7   order_purchase_timestamp        113105 non-null  object
 8   order_approved_at               113105 non-null  object
 9   order_delivered_carrier_date    113105 non-null  object
 10  order_delivered_customer_date   113105 non-null  object
 11  order_estimated_delivery_date   113105 non-null  object
 12  review_score                    113105 non-null  int64
 13  customer_unique_id              113105 non-null  object
 14  zip_code_prefix_customer        113105 non-null  int64
 15  lat_customer                    113105 non-null  float64
 16  lng_customer                    113105 non-null  float64
 17  customer_city                   113105 non-null  object
 18  customer_state                  113105 non-null  object
 19  product_id                      113105 non-null  object
 20  product_name_lenght             113105 non-null  float64
 21  product_description_lenght      113105 non-null  float64
 22  product_photos_qty              113105 non-null  float64
 23  product_weight_g                113105 non-null  float64
 24  product_length_cm               113105 non-null  float64
 25  product_height_cm               113105 non-null  float64
 26  product_width_cm                113105 non-null  float64
 27  order_item_id                   113105 non-null  int64
 28  seller_id                       113105 non-null  object
 29  shipping_limit_date             113105 non-null  object
 30  price                           113105 non-null  float64
 31  freight_value                   113105 non-null  float64
 32  zip_code_prefix_seller          113105 non-null  int64
 33  lat_seller                      113105 non-null  float64
 34  lng_seller                      113105 non-null  float64
 35  seller_city                     113105 non-null  object
 36  seller_state                    113105 non-null  object
 37  product_category_name           113105 non-null  object
 38  estimated_time                  113105 non-null  float64
 39  actual_time                     113105 non-null  float64
 40  diff_actual_estimated           113105 non-null  float64
 41  diff_purchased_approved         113105 non-null  float64
 42  diff_purchased_courrier         113105 non-null  float64
 43  distance                        113105 non-null  float64
 44  speed                           113105 non-null  float64
 45  same_state                      113105 non-null  int64
 46  same_city                       113105 non-null  int64
 47  late_shipping                   113105 non-null  int64
 48  high_freight                    113105 non-null  int64
 49  seller_share                    113105 non-null  float64
 50  bs_share                        113105 non-null  float64
 51  cust_share                      113105 non-null  float64
 52  bu_share                        113105 non-null  float64
 53  similarity                      113105 non-null  float64
 54  seller_category_share           113105 non-null  float64
 55  cat_seller_share                113105 non-null  float64
 56  cust_category_share             113105 non-null  float64
 57  cat_cust_share                  113105 non-null  float64
 58  similarity_using_cat            113105 non-null  float64
 59  size                            113105 non-null  float64
 60  delivery_day                    113105 non-null  int64
 61  delivery_date                   113105 non-null  int64
 62  delivery_month                  113105 non-null  int64
 63  delivery_hour                   113105 non-null  int64
 64  purchased_day                   113105 non-null  int64
 65  purchased_date                  113105 non-null  int64
 66  purchased_month                 113105 non-null  int64
 67  purchased_hour                  113105 non-null  int64
 68  num_of_customers_for_seller     113105 non-null  float64
```

```
 69  num_of_sellers_for_cust         113105 non-null  float64
 70  total_order_for_seller          113105 non-null  float64
dtypes: float64(35), int64(18), object(18)
memory usage: 61.3+ MB
```

In [4]:
```
#label encoding of seller_id
label = LabelEncoder()
seller = label.fit_transform(data.seller_id)
data["seller_id"] = seller


#label encoding of product id
label = LabelEncoder()
product = label.fit_transform(data.product_id)
data["product_id"] = product
```

In [5]:
```
#let us drop some of the columns which are not needed
data.drop(["order_id","customer_id","order_status","order_approved_at","order_delivered_carrier_date",
           "order_estimated_delivery_date","order_delivered_customer_date","customer_unique_id","customer_
          "seller_city","shipping_limit_date","seller_state","customer_state",
           "order_purchase_timestamp"],inplace=True,axis=1)
```

In [6]:
```
#shape of the data after dropping unnecessary columns
data.shape
```

Out[6]: (113105, 57)

In [7]:
```
data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 113105 entries, 0 to 113104
Data columns (total 57 columns):
 #   Column                        Non-Null Count   Dtype  
---  ------                        --------------   -----  
 0   payment_sequential            113105 non-null  int64  
 1   payment_type                  113105 non-null  object 
 2   payment_installments          113105 non-null  int64  
 3   payment_value                 113105 non-null  float64
 4   review_score                  113105 non-null  int64  
 5   zip_code_prefix_customer      113105 non-null  int64  
 6   lat_customer                  113105 non-null  float64
 7   lng_customer                  113105 non-null  float64
 8   product_id                    113105 non-null  int32  
 9   product_name_lenght           113105 non-null  float64
 10  product_description_lenght    113105 non-null  float64
 11  product_photos_qty            113105 non-null  float64
 12  product_weight_g              113105 non-null  float64
 13  product_length_cm             113105 non-null  float64
 14  product_height_cm             113105 non-null  float64
 15  product_width_cm              113105 non-null  float64
 16  order_item_id                 113105 non-null  int64  
 17  seller_id                     113105 non-null  int32  
 18  price                         113105 non-null  float64
 19  freight_value                 113105 non-null  float64
 20  zip_code_prefix_seller        113105 non-null  int64  
 21  lat_seller                    113105 non-null  float64
 22  lng_seller                    113105 non-null  float64
 23  product_category_name         113105 non-null  object 
 24  estimated_time                113105 non-null  float64
 25  actual_time                   113105 non-null  float64
 26  diff_actual_estimated         113105 non-null  float64
 27  diff_purchased_approved       113105 non-null  float64
 28  diff_purchased_courrier       113105 non-null  float64
 29  distance                      113105 non-null  float64
 30  speed                         113105 non-null  float64
 31  same_state                    113105 non-null  int64  
 32  same_city                     113105 non-null  int64  
 33  late_shipping                 113105 non-null  int64  
 34  high_freight                  113105 non-null  int64  
 35  seller_share                  113105 non-null  float64
 36  bs_share                      113105 non-null  float64
 37  cust_share                    113105 non-null  float64
 38  bu_share                      113105 non-null  float64
 39  similarity                    113105 non-null  float64
 40  seller_category_share         113105 non-null  float64
 41  cat_seller_share              113105 non-null  float64
 42  cust_category_share           113105 non-null  float64
 43  cat_cust_share                113105 non-null  float64
 44  similarity_using_cat          113105 non-null  float64
 45  size                          113105 non-null  float64
 46  delivery_day                  113105 non-null  int64  
 47  delivery_date                 113105 non-null  int64  
 48  delivery_month                113105 non-null  int64  
 49  delivery_hour                 113105 non-null  int64  
 50  purchased_day                 113105 non-null  int64  
 51  purchased_date                113105 non-null  int64  
 52  purchased_month               113105 non-null  int64  
 53  purchased_hour                113105 non-null  int64  
 54  num_of_customers_for_seller   113105 non-null  float64
 55  num_of_sellers_for_cust       113105 non-null  float64
 56  total_order_for_seller        113105 non-null  float64
dtypes: float64(35), int32(2), int64(18), object(2)
memory usage: 48.3+ MB
```

1.1 Stratified Splitting

In [8]:
```
data = data[data["review_score"]!=5]
Y = data["review_score"]
X = data
```

In [ ]:

In [9]:
```
#train test split with test size 25% and 75% of data as train
x_train,x_test,y_train,y_test = train_test_split(X,Y,test_size=0.25,stratify=Y,random_state=10)
```

In [10]:
```
print("Dimensions of the splitted data :")
print("Train: ",x_train.shape,y_train.shape)
print("Test: ",x_test.shape,y_test.shape)
```

```
Dimensions of the splitted data :
Train:  (36351, 57) (36351,)
Test:  (12117, 57) (12117,)
```

In [11]:
```
#check the distribution of each class in train,test as well as original data
print("% Distribution of class labels in the total data :")
print(round(data["review_score"].value_counts(normalize=True)*100,2))
print("*"*50)

print("% Distribution of class labels in the train data :")
print(round(x_train["review_score"].value_counts(normalize=True)*100,2))
print("*"*50)

print("% Distribution of class labels in the test data :")
print(round(x_test["review_score"].value_counts(normalize=True)*100,2))
print("*"*50)
```

```
% Distribution of class labels in the total data :
4    44.82
1    27.32
3    19.75
2     8.11
Name: review_score, dtype: float64
**************************************************
% Distribution of class labels in the train data :
4    44.82
1    27.32
3    19.75
2     8.10
Name: review_score, dtype: float64
**************************************************
% Distribution of class labels in the test data :
4    44.82
1    27.32
3    19.75
2     8.11
Name: review_score, dtype: float64
**************************************************
```

- Distribution of each class label is same in train.test and original data.

Data is highly imbalanced. % of class 2 is very less. So we might face problem of misclassification due to this imbalanced data. Before applying any advanced techniques, let us build simple models and check how model will perform with this data.

let us use simple CountVectorizer for categorical data.

1.2 Featurization:

1.2.1 Vectorization of categorical variables:

In [12]:
```
from sklearn.feature_extraction.text import CountVectorizer
```

1. payment_type

In [13]:
```
#payment_type
vec = CountVectorizer()

vec.fit(x_train["payment_type"].values)

x_tr_pay_type = vec.transform(x_train.payment_type.values)
x_te_pay_type = vec.transform(x_test.payment_type.values)

print(x_tr_pay_type.shape)
print(x_te_pay_type.shape)
```

```
(36351, 4)
(12117, 4)
```

2. order_item_id

In [14]:
```
x_train.order_item_id = x_train.order_item_id.astype(str)
x_test.order_item_id = x_test.order_item_id.astype(str)
```

In [15]:
```
#order_item_id
vec = CountVectorizer(vocabulary=range(1,22))

vec.fit(x_train["order_item_id"])

x_tr_id = vec.transform(x_train.order_item_id)
x_te_id = vec.transform(x_test.order_item_id)

print(x_tr_id.shape)

print(x_te_id.shape)
```

```
(36351, 21)
(12117, 21)
```

3. product_category_name

In [16]:
```
#product_category_name
vec = CountVectorizer()

vec.fit(x_train["product_category_name"].values)

x_tr_cat = vec.transform(x_train.product_category_name.values)
#x_cv_cat = vec.transform(x_cv.product_category_name.values).toarray()
x_te_cat = vec.transform(x_test.product_category_name.values)

print(x_tr_cat.shape)
#print(x_cv_cat.shape)
print(x_te_cat.shape)
```

```
(36351, 72)
(12117, 72)
```

In [ ]:

1.2.2 Binary features

In [17]:
```
x_tr_same_state = x_train.same_state.values.reshape(-1,1)
x_te_same_state = x_test.same_state.values.reshape(-1,1)

x_tr_same_city = x_train.same_city.values.reshape(-1,1)
x_te_same_city = x_test.same_city.values.reshape(-1,1)

x_tr_late_shipping = x_train.late_shipping.values.reshape(-1,1)
x_te_late_shipping = x_test.late_shipping.values.reshape(-1,1)

x_tr_high_freight = x_train.high_freight.values.reshape(-1,1)
x_te_high_freight = x_test.high_freight.values.reshape(-1,1)
```

1.2.3 Numrical features

In [18]:
```
def scaling(train_data,test_data):
    """This function will standardize the numerical data"""
    norm = StandardScaler()

    norm.fit(train_data.values)

    x_tr_num = norm.transform(train_data.values)
    x_te_num = norm.transform(test_data.values)


    return x_tr_num,x_te_num
```

In [19]:
```
data.columns
```

Out[19]:
```
Index(['payment_sequential', 'payment_type', 'payment_installments',
       'payment_value', 'review_score', 'zip_code_prefix_customer',
       'lat_customer', 'lng_customer', 'product_id', 'product_name_lenght',
       'product_description_lenght', 'product_photos_qty', 'product_weight_g',
       'product_length_cm', 'product_height_cm', 'product_width_cm',
       'order_item_id', 'seller_id', 'price', 'freight_value',
       'zip_code_prefix_seller', 'lat_seller', 'lng_seller',
       'product_category_name', 'estimated_time', 'actual_time',
       'diff_actual_estimated', 'diff_purchased_approved',
       'diff_purchased_courrier', 'distance', 'speed', 'same_state',
       'same_city', 'late_shipping', 'high_freight', 'seller_share',
       'bs_share', 'cust_share', 'bu_share', 'similarity',
       'seller_category_share', 'cat_seller_share', 'cust_category_share',
       'cat_cust_share', 'similarity_using_cat', 'size', 'delivery_day',
       'delivery_date', 'delivery_month', 'delivery_hour', 'purchased_day',
       'purchased_date', 'purchased_month', 'purchased_hour',
       'num_of_customers_for_seller', 'num_of_sellers_for_cust',
       'total_order_for_seller'],
      dtype='object')
```

In [20]:
```
#data to be standardized
tr = x_train[["payment_sequential","payment_installments","payment_value","seller_id","product_id","seller
              "bs_share","cust_share",
          "lat_customer","lng_customer","lat_seller","lng_seller","product_name_lenght","product_descripti
           "product_photos_qty","product_weight_g","size","price","delivery_day","delivery_date","delivery
              "delivery_hour","purchased_day","purchased_date","purchased_month","purchased_hour","num_of_
              "num_of_sellers_for_cust","total_order_for_seller",
           "freight_value","estimated_time","actual_time","diff_actual_estimated","diff_purchased_approved
           "diff_purchased_courrier","distance","speed","similarity","similarity_using_cat"]]

te = x_test[["payment_sequential","payment_installments","payment_value","seller_id","product_id","seller_
              "bs_share","cust_share",
          "lat_customer","lng_customer","lat_seller","lng_seller","product_name_lenght","product_descripti
           "product_photos_qty","product_weight_g","size","price","delivery_day","delivery_date","delivery
              "delivery_hour","purchased_day","purchased_date","purchased_month","purchased_hour","num_of_
              "num_of_sellers_for_cust","total_order_for_seller",
           "freight_value","estimated_time","actual_time","diff_actual_estimated","diff_purchased_approved
           "diff_purchased_courrier","distance","speed","similarity","similarity_using_cat"]]
```

In [21]:
```
#standardizing
x_tr_num,x_te_num = scaling(tr,te)
```

In [22]:
```
from scipy.sparse import hstack
#horizontal stacking of all the features
train = hstack((x_tr_pay_type,x_tr_id,x_tr_cat,x_tr_num,x_tr_same_state,
                   x_tr_same_city,x_tr_late_shipping,x_tr_high_freight)).toarray()

test = hstack((x_te_pay_type,x_te_id,x_te_cat,x_te_num,x_te_same_state,
                  x_te_same_city,x_te_late_shipping,x_te_high_freight)).toarray()
```

In [23]:
```
#shape of final train and test data
print("Shape of train data : ",train.shape)
print("Shape of test data : ",test.shape)
```

```
Shape of train data :  (36351, 141)
Shape of test data :  (12117, 141)
```

In [24]:
```
#reset the index of target variable
y_trains = y_train.reset_index()
y_train = y_trains["review_score"]

y_tests = y_test.reset_index()
y_test = y_tests["review_score"]
```

1.3 ML Models

Plotting Confusion matrix

In [25]:
```
# This function plots the confusion matrices given y_i, y_i_hat.
def plot_confusion_matrix(test_y, predict_y):
    """This function will plot confusion matrix, precision matrix and recall matrix"""
    C = confusion_matrix(test_y, predict_y)
    A =(((C.T)/(C.sum(axis=1))).T)
    B =(C/C.sum(axis=0))

    labels = [1,2,3,4]
    # representing A in heatmap format
    print("-"*20, "Confusion matrix", "-"*20)
    plt.figure(figsize=(20,7))
    sns.heatmap(C, annot=True, cmap="YlGnBu", fmt=".3f", xticklabels=labels, yticklabels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()

    print("-"*20, "Precision matrix (Columm Sum=1)", "-"*20)
    plt.figure(figsize=(20,7))
    sns.heatmap(B, annot=True, cmap="YlGnBu", fmt=".3f", xticklabels=labels, yticklabels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()

    # representing B in heatmap format
    print("-"*20, "Recall matrix (Row sum=1)", "-"*20)
    plt.figure(figsize=(20,7))
    sns.heatmap(A, annot=True, cmap="YlGnBu", fmt=".3f", xticklabels=labels, yticklabels=labels)
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()
```

k-fold cross validation

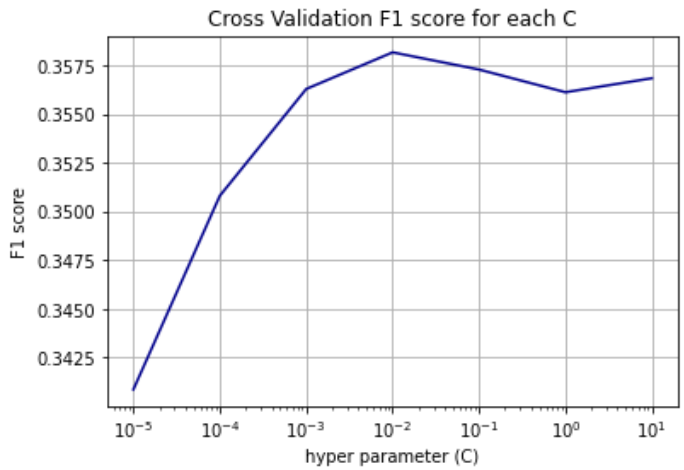
In [26]:
```
def kfold(k,model,trains,y_trains):
    """This function will do stratified k-fold cross_validation"""
    kf = StratifiedKFold(n_splits=k)

    cv_f1_score = []
    for tr_ind,cv_ind in kf.split(trains,y_trains):

        x_tr,x_cv,y_tr,y_cv = trains[tr_ind],trains[cv_ind],y_trains[tr_ind],y_trains[cv_ind]

        model.fit(x_tr,y_tr)
        pred_cv = model.predict(x_cv)
        cv_f1_score.append((f1_score(y_cv,pred_cv,average="macro",labels=[1,2,3,4])))

    return np.mean(cv_f1_score)
```

1.3.1 Logistic regression

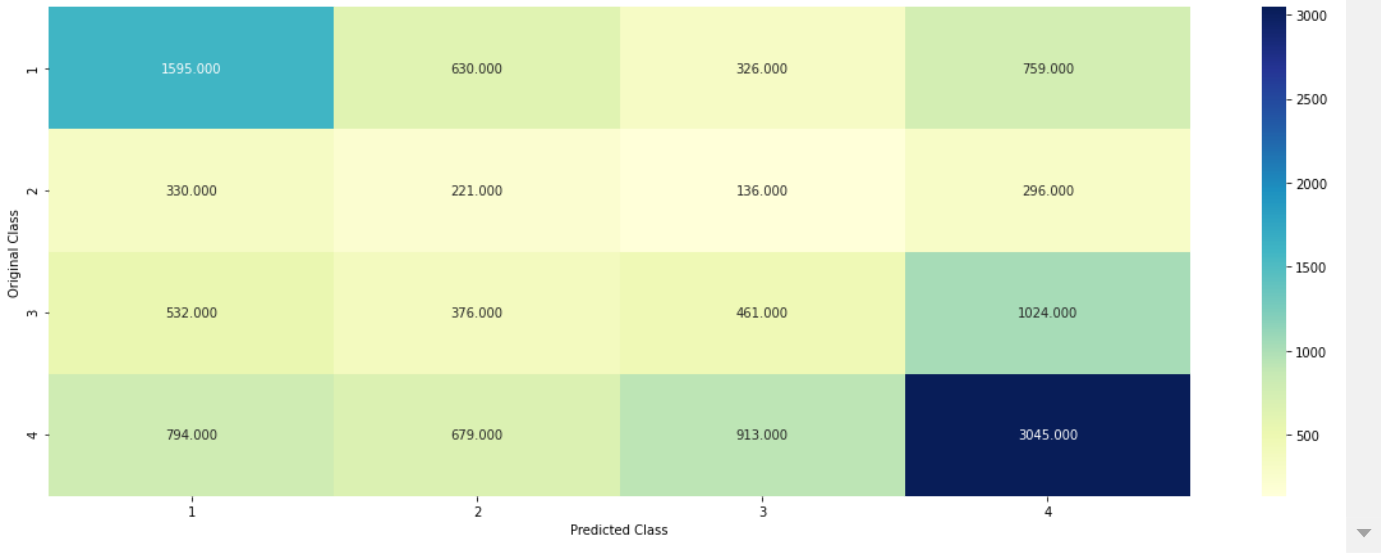
One vs Rest with class_weight = balanced

In [27]:
```
C=[0.00001,0.0001,0.001,0.01,0.1,1,10]

f1_scores = []
for i in C:
    model = None
    model = LogisticRegression(C=i,class_weight="balanced")
    k_fold_score = kfold(5,model,train,y_train)
    f1_scores.append(k_fold_score)
    print("Macro F1 score at C={} is {} ".format(i,k_fold_score))



print("*"*50)
plt.plot(C,f1_scores,color="darkblue")
plt.xscale("log")
plt.grid()
plt.title("Cross Validation F1 score for each C")
plt.xlabel("hyper parameter (C)")
plt.ylabel("F1 score")
plt.show()

best_param = C[np.argmax(f1_scores)]

model = None
model = LogisticRegression(C=i,class_weight="balanced")
model.fit(train,y_train)


print("*"*50)
print("Train F1 score at {} is :{}".format(best_param, f1_score(y_train,model.predict(train),labels=model.
print("*"*50)
print("test F1 score at {} is :{}".format(best_param, f1_score(y_test,model.predict(test),labels=model.cla


#plotting confusion matrix
predicted = model.predict(test)
plot_confusion_matrix(y_test,predicted)
```

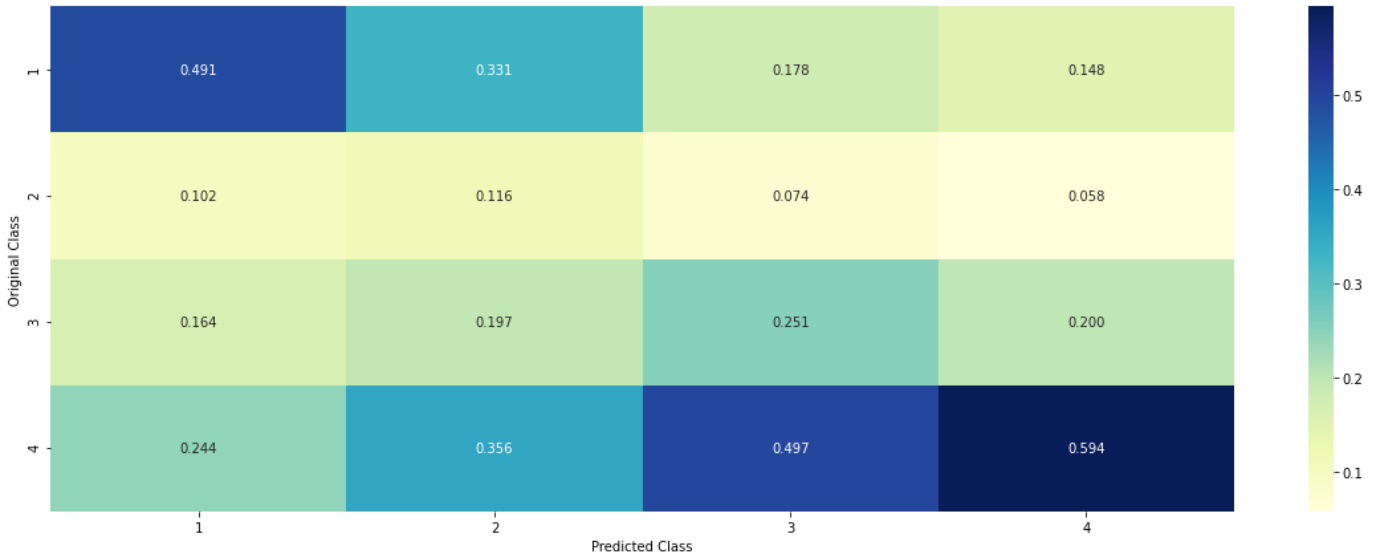
```
Macro F1 score at C=1e-05 is 0.3408694726197833
Macro F1 score at C=0.0001 is 0.3508066060297175
Macro F1 score at C=0.001 is 0.3562882159133647
Macro F1 score at C=0.01 is 0.35816843119316666
Macro F1 score at C=0.1 is 0.3572851056412578
Macro F1 score at C=1 is 0.3561208072083494
Macro F1 score at C=10 is 0.3568396308276774
**************************************************
```



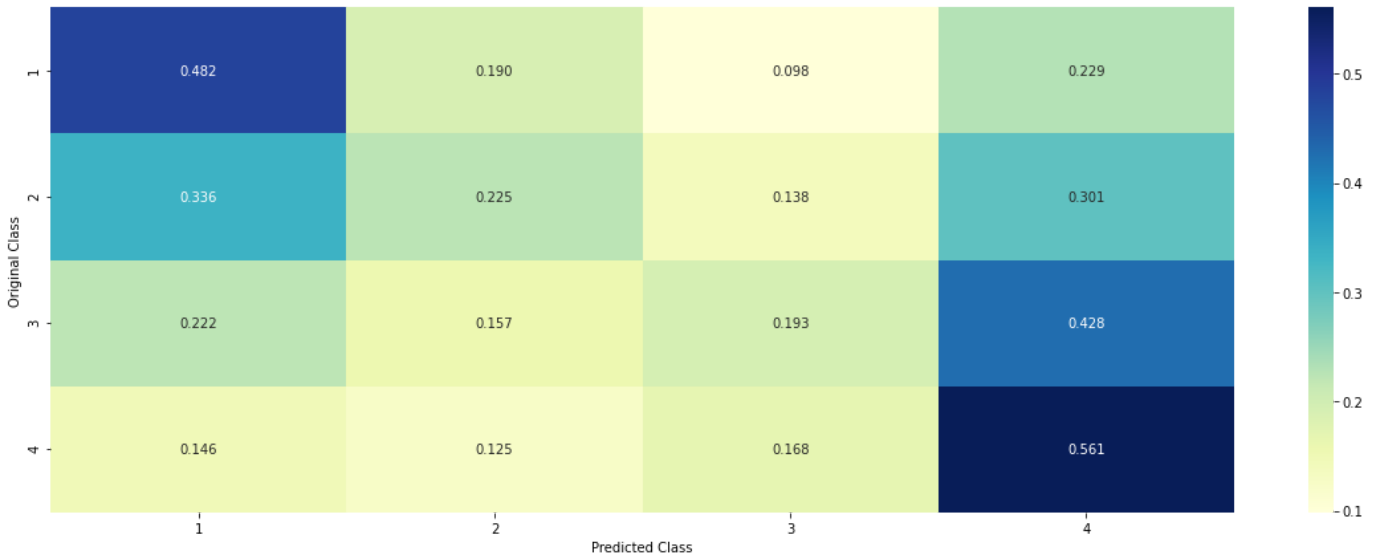

```
**************************************************
Train F1 score at 0.01 is :0.3681109726049413
**************************************************
test F1 score at 0.01 is :0.358549166584471
-------------------- Confusion matrix --------------------
```



---------- Precision matrix (Columm Sum=1) ----------



---------- Recall matrix (Row sum=1) ----------

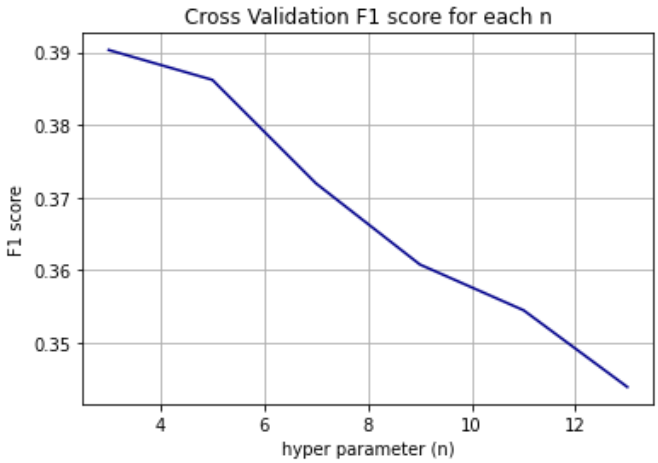


1.3.3 KNN

In [28]:
```
from sklearn.neighbors import KNeighborsClassifier
```

In [29]:
```
n=[3,5,7,9,11,13]

f1_scores = []
for i in n:
    model = None
    model = KNeighborsClassifier(n_neighbors=i)
    k_fold_score = kfold(5,model,train,y_train)
    f1_scores.append(k_fold_score)
    print("Macro F1 score at n={} is {} ".format(i,k_fold_score))



print("*"*50)
plt.plot(n,f1_scores,color="darkblue")

plt.grid()
plt.title("Cross Validation F1 score for each n")
plt.xlabel("hyper parameter (n)")
plt.ylabel("F1 score")
plt.show()

best_param = n[np.argmax(f1_scores)]

model = None
model = KNeighborsClassifier(n_neighbors=best_param)
model.fit(train,y_train)


print("*"*50)
print("Train F1 score at {} is :{}".format(best_param, f1_score(y_train,model.predict(train),labels=model.
print("*"*50)
print("test F1 score at {} is :{}".format(best_param, f1_score(y_test,model.predict(test),labels=model.cla


#plotting confusion matrix
predicted = model.predict(test)
plot_confusion_matrix(y_test,predicted)
```

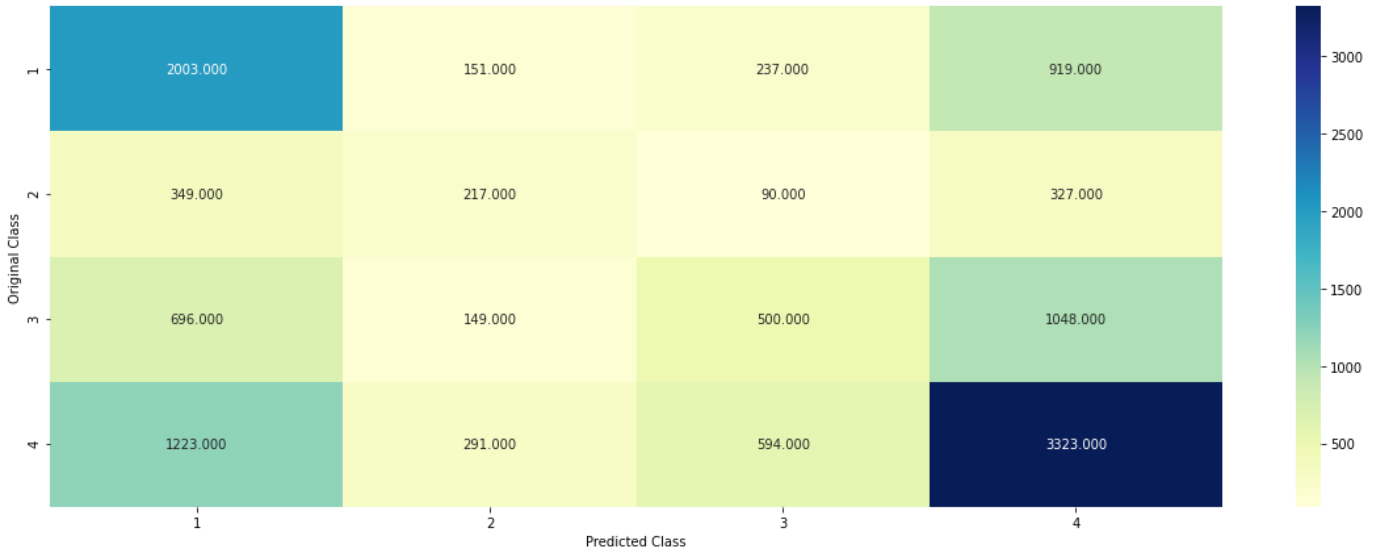
```
Macro F1 score at n=3 is 0.39032718850195314
Macro F1 score at n=5 is 0.3862115895646426
Macro F1 score at n=7 is 0.3719419243213421
Macro F1 score at n=9 is 0.360790847235193
Macro F1 score at n=11 is 0.35448864080785264
Macro F1 score at n=13 is 0.34392322863482117
**************************************************
```



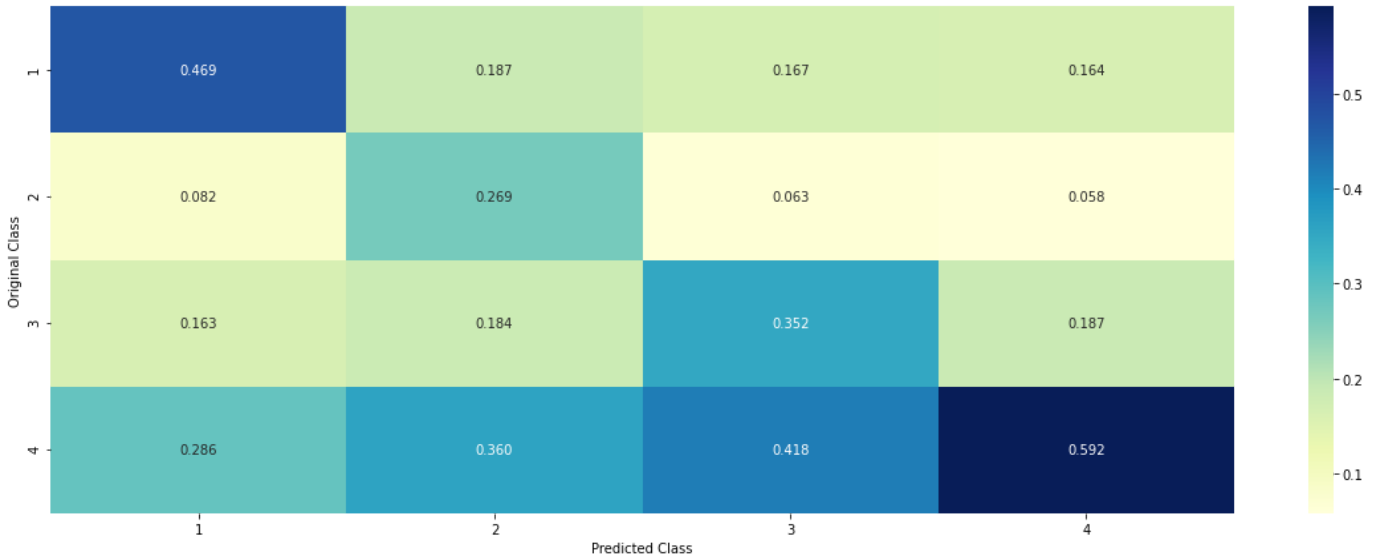

```
**************************************************
Train F1 score at 3 is :0.6909387502185933
**************************************************
```

test F1 score at 3 is :0.4086244552678359

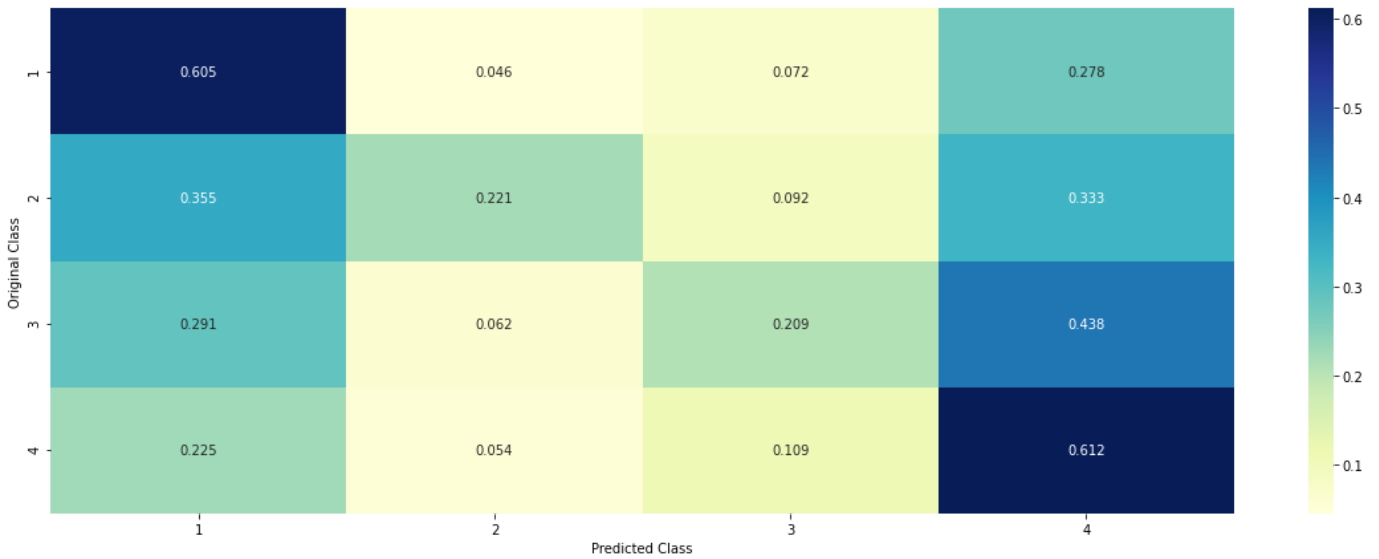
---------- Confusion matrix ----------



---------- Precision matrix (Columm Sum=1) ----------



---------- Recall matrix (Row sum=1) ----------

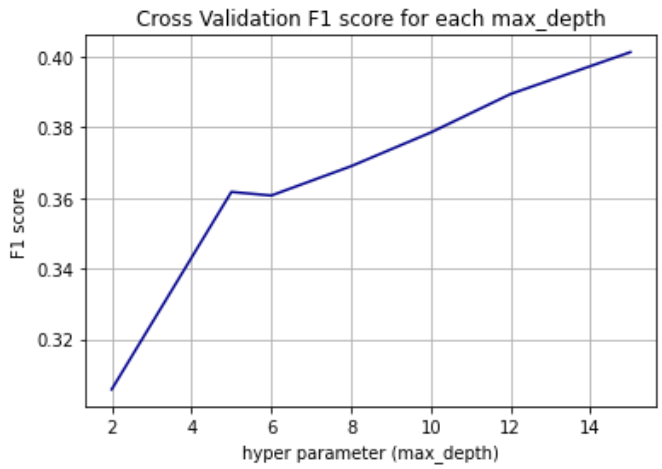


1.3.4. Decision Tree

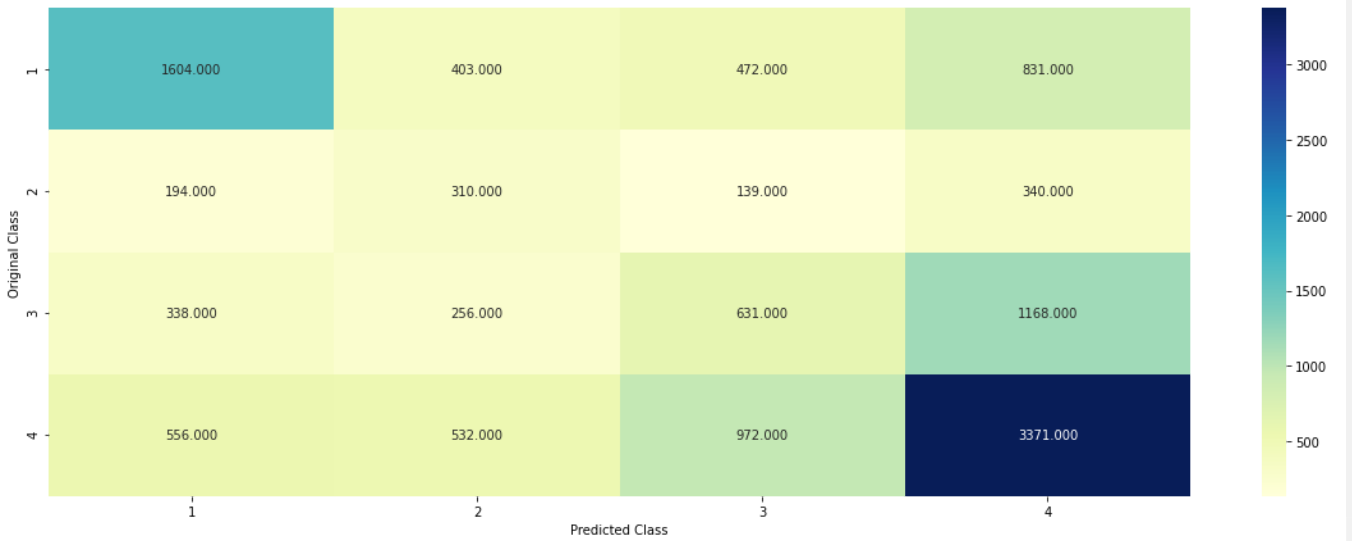
In [30]:
```
from sklearn.tree import DecisionTreeClassifier
```

In [31]:
```
max_depth=[2,5,6,8,10,12,15]

f1_scores = []
for i in max_depth:
    model = None
    model = DecisionTreeClassifier(max_depth=i,class_weight="balanced")
    k_fold_score = kfold(5,model,train,y_train)
    f1_scores.append(k_fold_score)
    print("Macro F1 score at n={} is {} ".format(i,k_fold_score))



print("*"*50)
plt.plot(max_depth,f1_scores,color="darkblue")

plt.grid()
plt.title("Cross Validation F1 score for each max_depth")
plt.xlabel("hyper parameter (max_depth)")
plt.ylabel("F1 score")
plt.show()

best_param = max_depth[np.argmax(f1_scores)]

model = None
model = DecisionTreeClassifier(max_depth=best_param,class_weight="balanced")
model.fit(train,y_train)


print("*"*50)
print("Train F1 score at {} is :{}".format(best_param, f1_score(y_train,model.predict(train),labels=model.
print("*"*50)
print("test F1 score at {} is :{}".format(best_param, f1_score(y_test,model.predict(test),labels=model.cla


#plotting confusion matrix
predicted = model.predict(test)
plot_confusion_matrix(y_test,predicted)
```

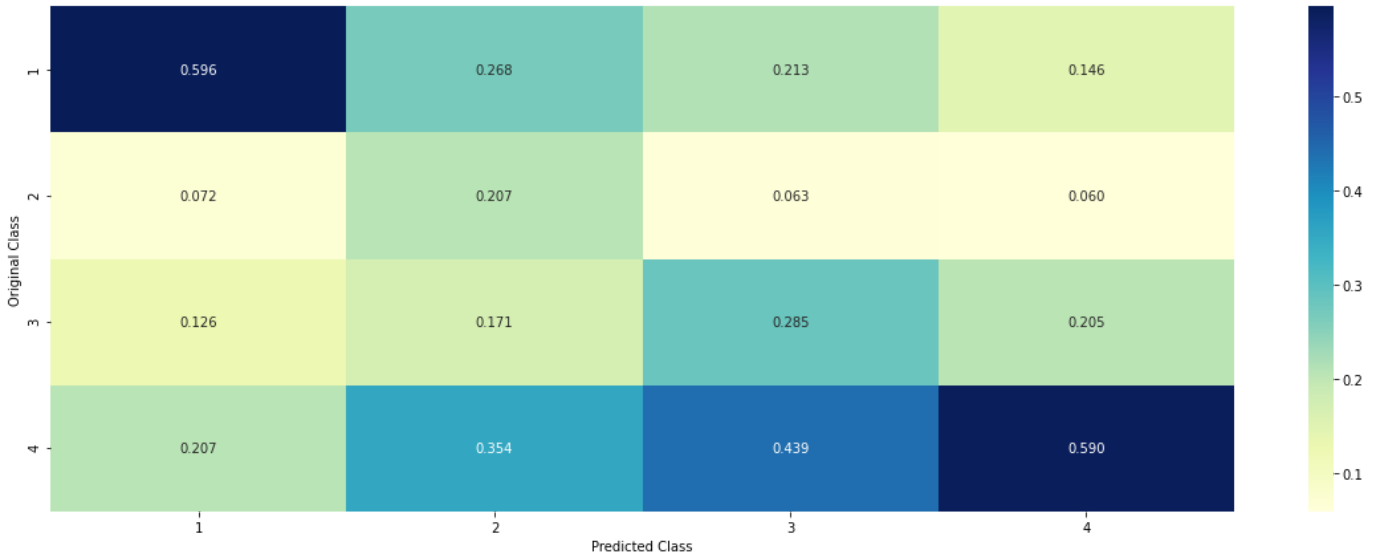
```
Macro F1 score at n=2 is 0.305879001111935
Macro F1 score at n=5 is 0.36170352428663005
Macro F1 score at n=6 is 0.36068181314349834
Macro F1 score at n=8 is 0.36896634903191633
Macro F1 score at n=10 is 0.3785064920310101
Macro F1 score at n=12 is 0.38937902359723175
Macro F1 score at n=15 is 0.40119881592265144
**************************************************
```



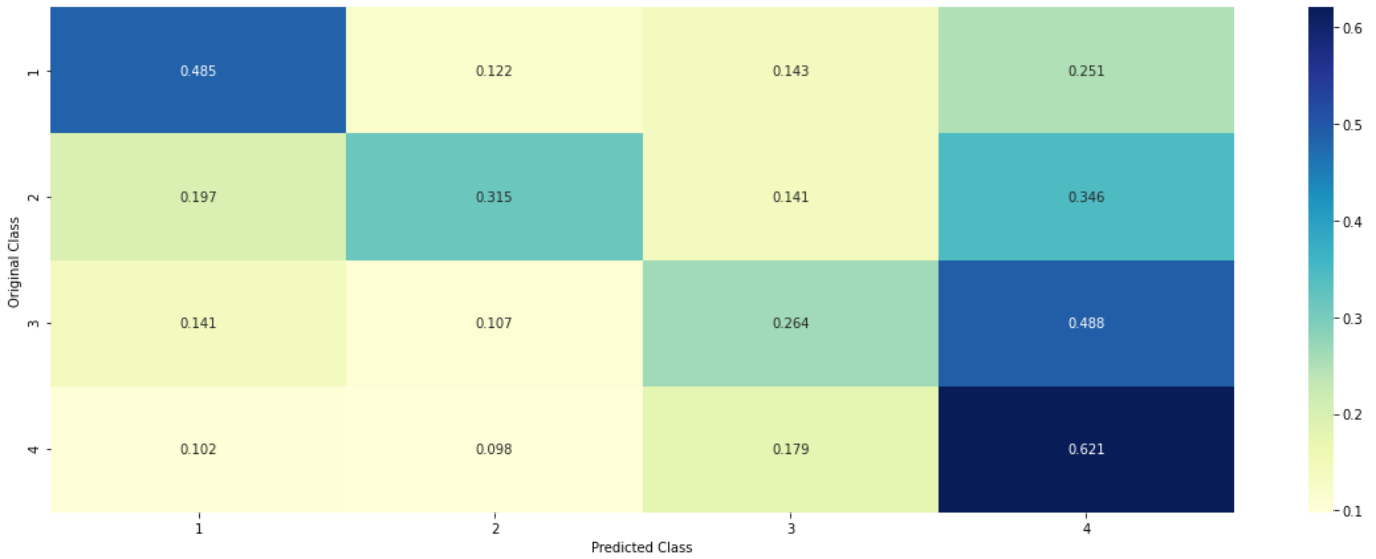

```
**************************************************
Train F1 score at 15 is :0.5752756308273197
**************************************************
test F1 score at 15 is :0.4157922606719481
-------------------- Confusion matrix --------------------
```



---------- Precision matrix (Columm Sum=1) ----------



---------- Recall matrix (Row sum=1) ----------



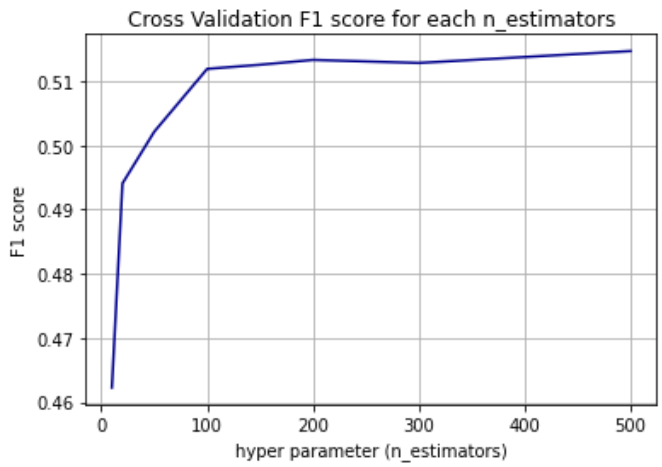
In [ ]:

1.3.5. Random Forest classifier

In [32]:
```
from sklearn.ensemble import RandomForestClassifier
```

In [33]:
```
n_estimators=[10,20,50,100,150,200,300,500]


f1_scores = []
for i in n_estimators:
    model = None
    model = RandomForestClassifier(n_estimators=i,class_weight="balanced")
    k_fold_score = kfold(5,model,train,y_train)
    f1_scores.append(k_fold_score)
    print("Macro F1 score at n={} is {} ".format(i,k_fold_score))



print("*"*50)
plt.plot(n_estimators,f1_scores,color="darkblue")

plt.grid()
plt.title("Cross Validation F1 score for each n_estimators")
plt.xlabel("hyper parameter (n_estimators)")
plt.ylabel("F1 score")
plt.show()

best_param = n_estimators[np.argmax(f1_scores)]

model = None
model = RandomForestClassifier(n_estimators=best_param,class_weight="balanced")
model.fit(train,y_train)


print("*"*50)
print("Train F1 score at {} is :{}".format(best_param, f1_score(y_train,model.predict(train),labels=model.
print("*"*50)
print("test F1 score at {} is :{}".format(best_param, f1_score(y_test,model.predict(test),labels=model.cla


#plotting confusion matrix
predicted = model.predict(test)
plot_confusion_matrix(y_test,predicted)
```

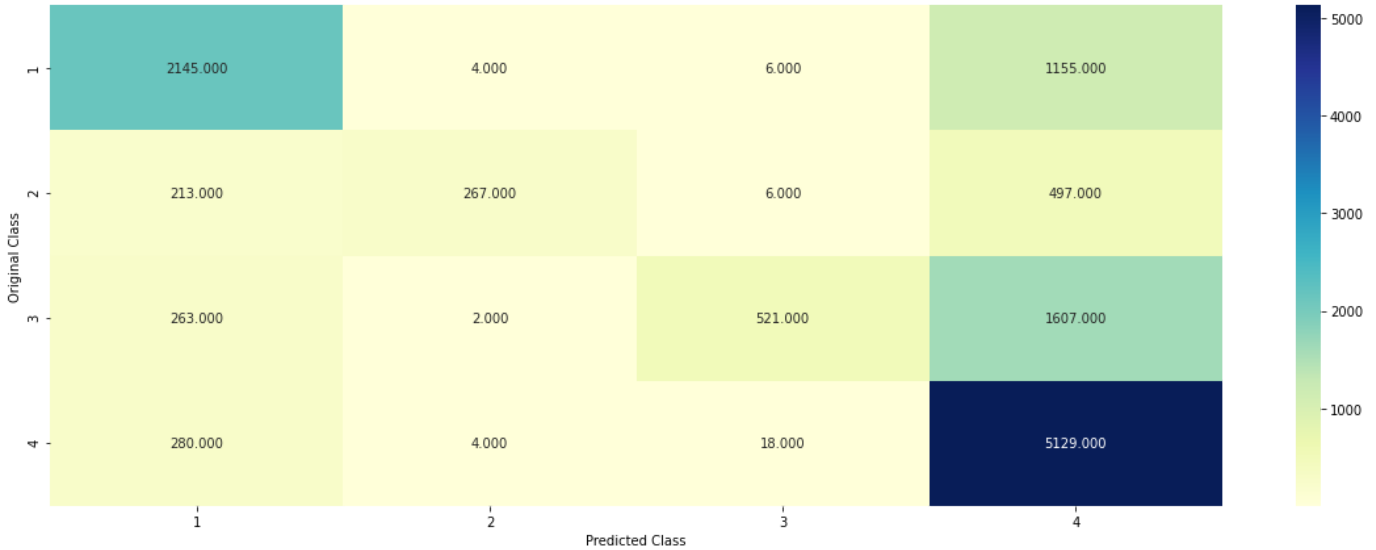
```
Macro F1 score at n=10 is 0.46226412790634697
Macro F1 score at n=20 is 0.4940921825780281
Macro F1 score at n=50 is 0.5021446392695073
Macro F1 score at n=100 is 0.5119435620917232
Macro F1 score at n=150 is 0.5125885537504458
Macro F1 score at n=200 is 0.5133419960153349
Macro F1 score at n=300 is 0.5128666790986646
Macro F1 score at n=500 is 0.5147210814540222
**************************************************
```



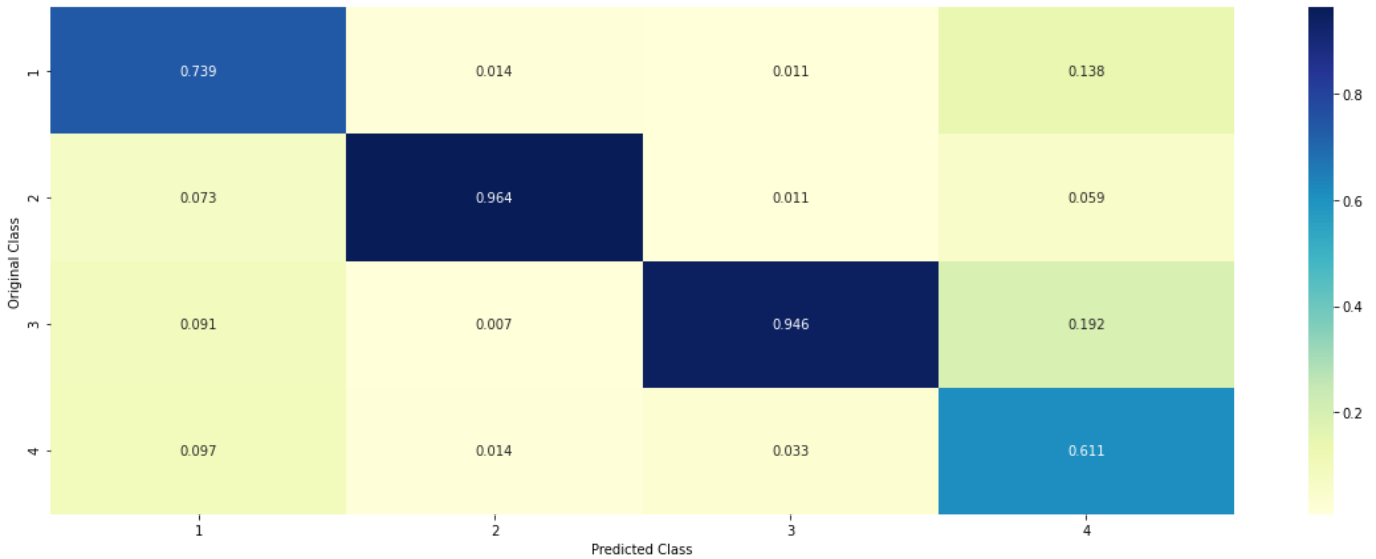

```
**************************************************
Train F1 score at 500 is :0.9975734278864823
**************************************************
```

test F1 score at 500 is :0.5526927705765561

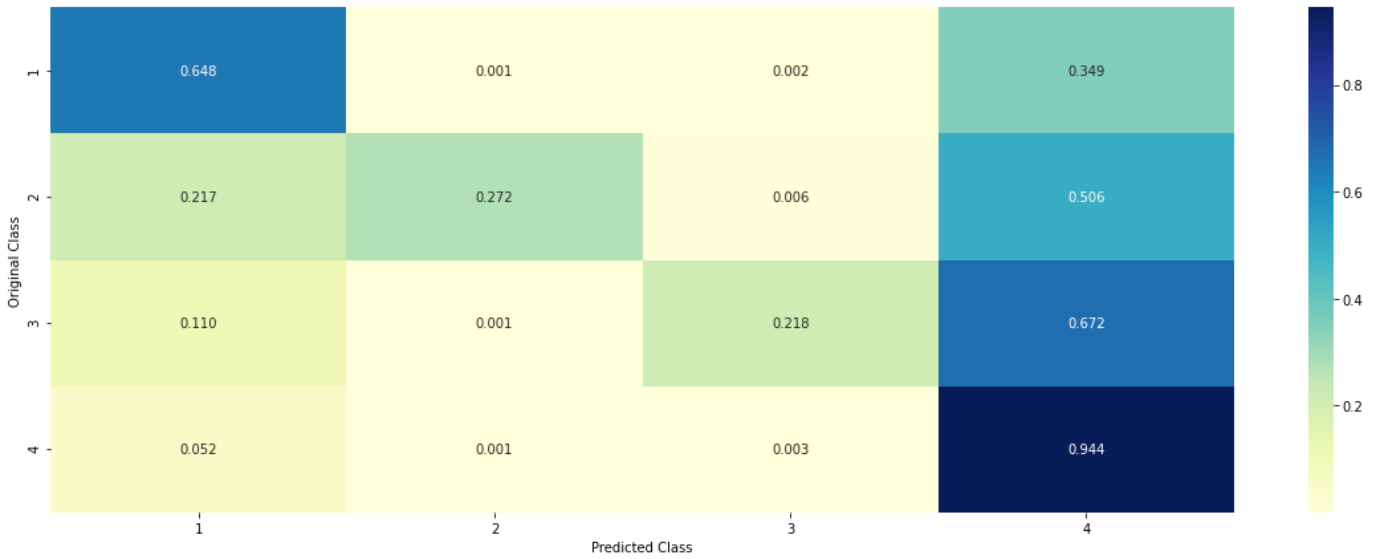
---------- Confusion matrix ----------



---------- Precision matrix (Columm Sum=1) ----------



---------- Recall matrix (Row sum=1) ----------

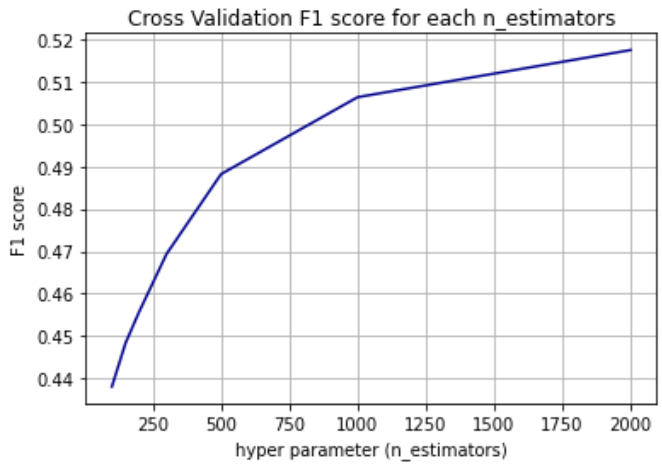


1.3.6. LightGBM

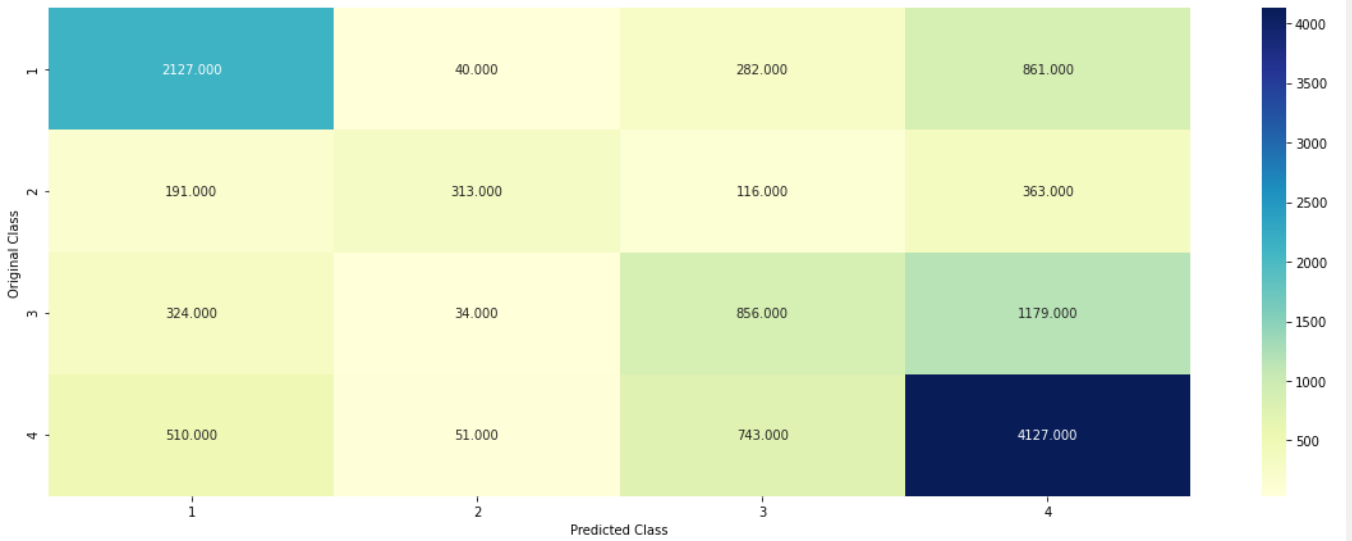
In [36]:
```
import lightgbm as lgb
```

In [37]:
```
n_estimators=[100,150,200,300,500,1000,2000]

f1_scores = []
for i in n_estimators:
    model = None
    model = lgb.LGBMClassifier(n_estimators=i,class_weight="balanced",boosting_type ="goss")
    k_fold_score = kfold(5,model,train,y_train)
    f1_scores.append(k_fold_score)
    print("Macro F1 score at n={} is {} ".format(i,k_fold_score))



print("*"*50)
plt.plot(n_estimators,f1_scores,color="darkblue")

plt.grid()
plt.title("Cross Validation F1 score for each n_estimators")
plt.xlabel("hyper parameter (n_estimators)")
plt.ylabel("F1 score")
plt.show()

best_n = n_estimators[np.argmax(f1_scores)]


model = None
model = lgb.LGBMClassifier(n_estimators=best_n,class_weight='balanced',boosting_type="goss")
model.fit(train,y_train)


print("*"*50)
print("Train F1 score at {} is  :{} ".format(best_n, f1_score(y_train,model.predict(train),labels=model.cl
print("*"*50)
print("test F1 score at {} is :{} ".format(best_n, f1_score(y_test,model.predict(test),labels=model.classe


#plotting confusion matrix

predicted = model.predict(test)
plot_confusion_matrix(y_test,predicted)
```

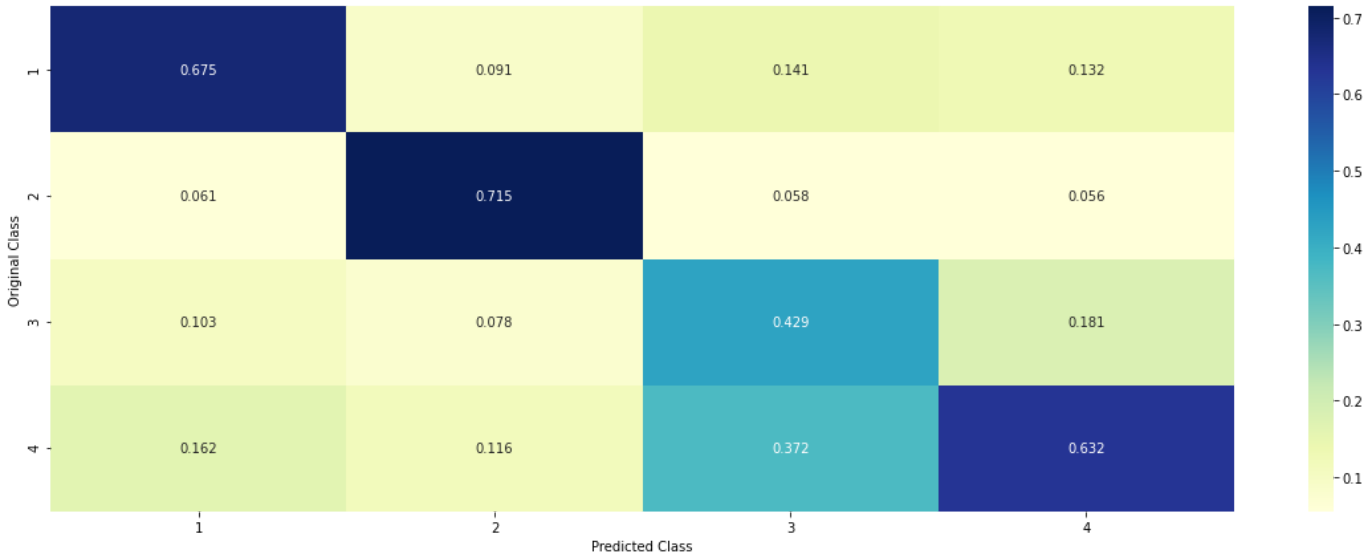
```
Macro F1 score at n=100 is 0.4380547859100788
Macro F1 score at n=150 is 0.4483338364155416
Macro F1 score at n=200 is 0.45573070077347655
Macro F1 score at n=300 is 0.46934927527792114
Macro F1 score at n=500 is 0.4882244550974746
Macro F1 score at n=1000 is 0.5063847020110472
Macro F1 score at n=2000 is 0.517508382787191
**************************************************
```



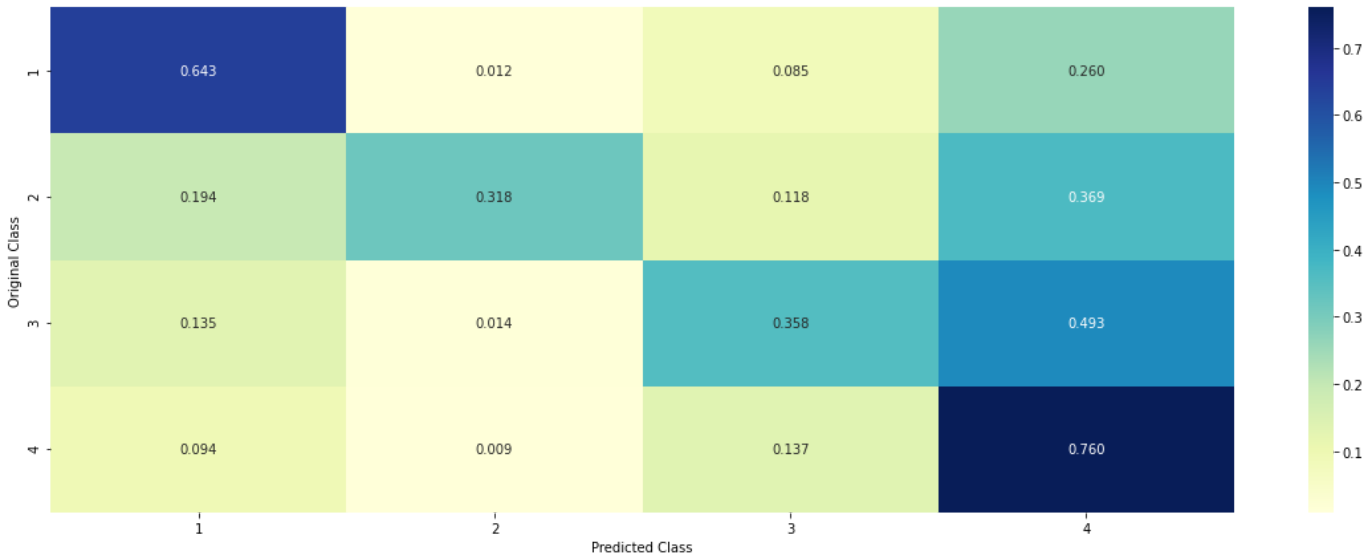

```
**************************************************
Train F1 score at 2000 is  :0.9975734530666492
**************************************************
test F1 score at 2000 is :0.544724564220289
-------------------- Confusion matrix --------------------
```



---------- Precision matrix (Columm Sum=1) ----------



---------- Recall matrix (Row sum=1) ----------



In [38]:
```
print(model.feature_importances_)
```

```
[  279   289   109   156     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0
     0     8    24    10     0    40   177   185   256     9     0    20
     0     5     0     9   230    91    99    43    22   141    10     3
     0    32     0   114     0   103    22     9     0     5    39     0
    22    23     0   250    39     0   125   270    47    14     0    37
    72   255    15    22     0     0    79    17     0    83    62     0
     0   150   150     0    16    53     0   286    89     8   158   173
   123   142  2793  8023  7508  9462  5320   605  5044   569  8849  9224
  6718  6735  5938  8703  1899  6612  7475  7541  2621  6302  2943  5014
  2835  6096  2918  5428  4710  1013     0  8221  8808  8382  9012 10395
 10038  7106  8487  5901  8718   132   120   297   166]
```

In [39]:
```
##########################################################################################################################
```

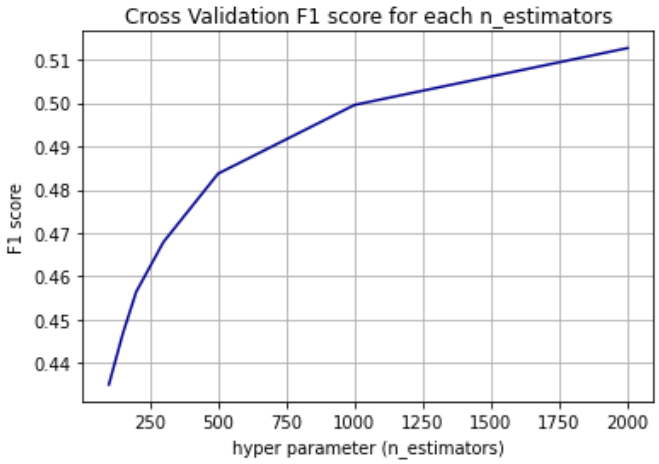
Feature selection

In [40]:
```
#https://www.analyticsvidhya.com/blog/2020/10/feature-selection-techniques-in-machine-learning/

from sklearn.feature_selection import SelectKBest,f_classif

features = SelectKBest(f_classif,k=60)
train_features = features.fit_transform(train,y_train)
test_features = features.transform(test)
```

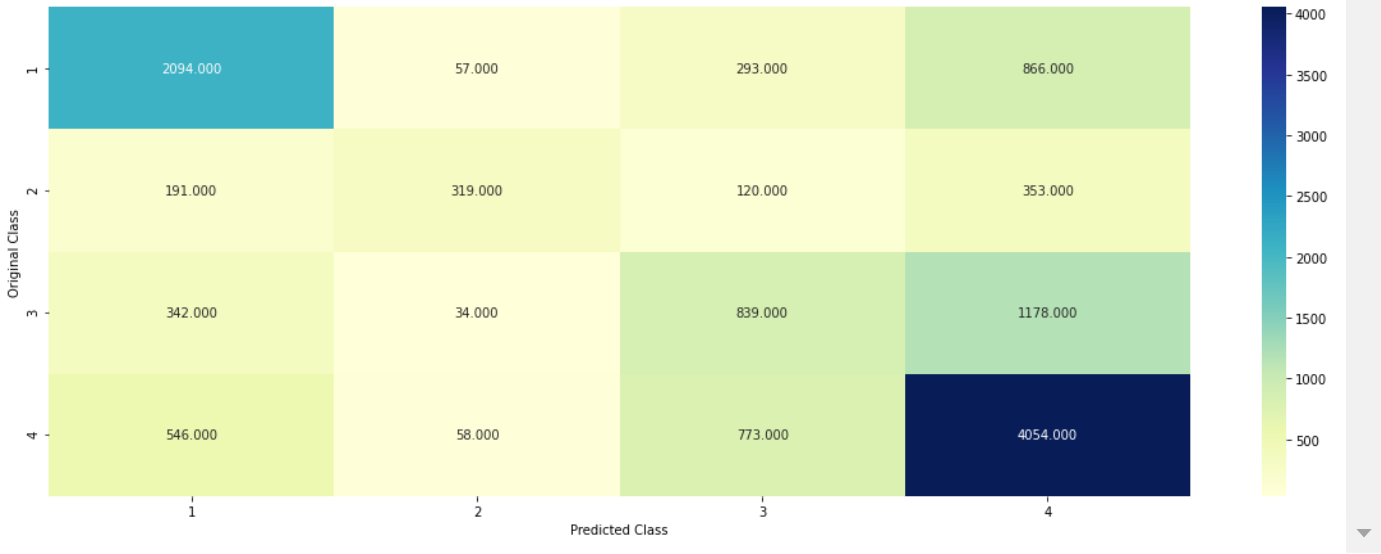
LGBM

In [41]:
```
n_estimators=[100,150,200,300,500,1000,2000]

f1_scores = []
for i in n_estimators:
    model = None
    model = lgb.LGBMClassifier(n_estimators=i,class_weight="balanced",boosting_type ="goss")
    k_fold_score = kfold(5,model,train_features,y_train)
    f1_scores.append(k_fold_score)
    print("Macro F1 score at n={} is {} ".format(i,k_fold_score))



print("*"*50)
plt.plot(n_estimators,f1_scores,color="darkblue")

plt.grid()
plt.title("Cross Validation F1 score for each n_estimators")
plt.xlabel("hyper parameter (n_estimators)")
plt.ylabel("F1 score")
plt.show()

best_n = n_estimators[np.argmax(f1_scores)]


model = None
model = lgb.LGBMClassifier(n_estimators=best_n,class_weight='balanced',boosting_type="goss")
model.fit(train_features,y_train)


print("*"*50)
print("Train F1 score at {} is  :{} ".format(best_n, f1_score(y_train,model.predict(train_features),labels
print("*"*50)
print("test F1 score at {} is :{} ".format(best_n, f1_score(y_test,model.predict(test_features),labels=mod


#plotting confusion matrix

predicted = model.predict(test_features)
plot_confusion_matrix(y_test,predicted)
```

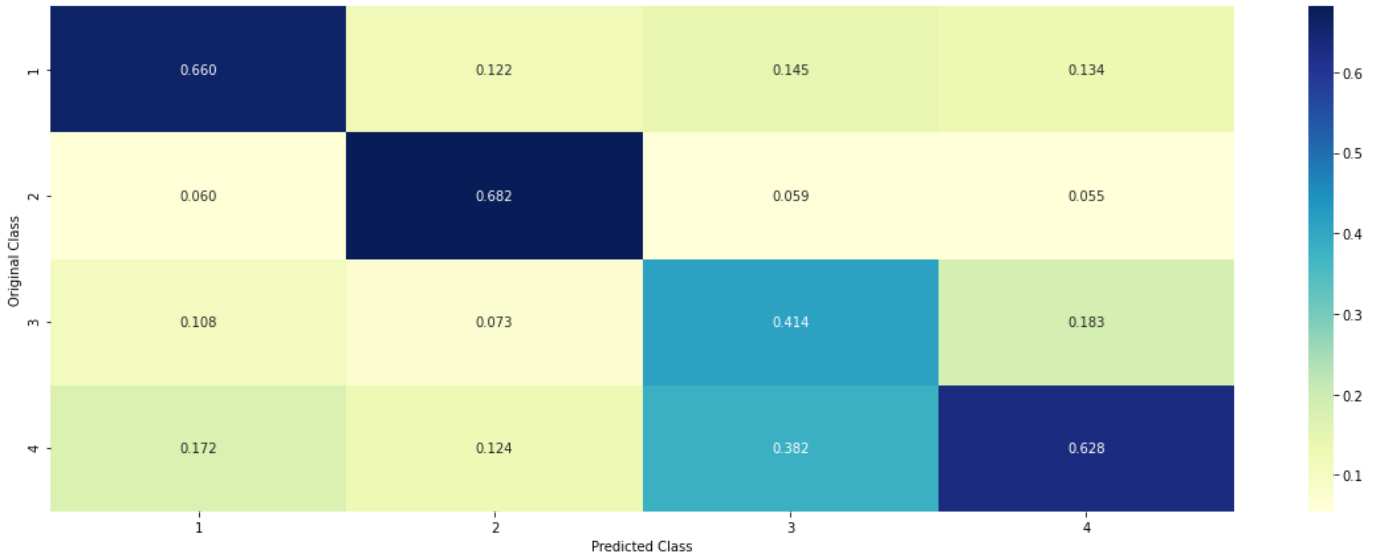
```
Macro F1 score at n=100 is 0.4350576594814185
Macro F1 score at n=150 is 0.4466000278945315
Macro F1 score at n=200 is 0.4564406051093023
Macro F1 score at n=300 is 0.46793762513066595
Macro F1 score at n=500 is 0.4836929832980411
Macro F1 score at n=1000 is 0.49953966899336455
Macro F1 score at n=2000 is 0.5126493516544504
**************************************************
```



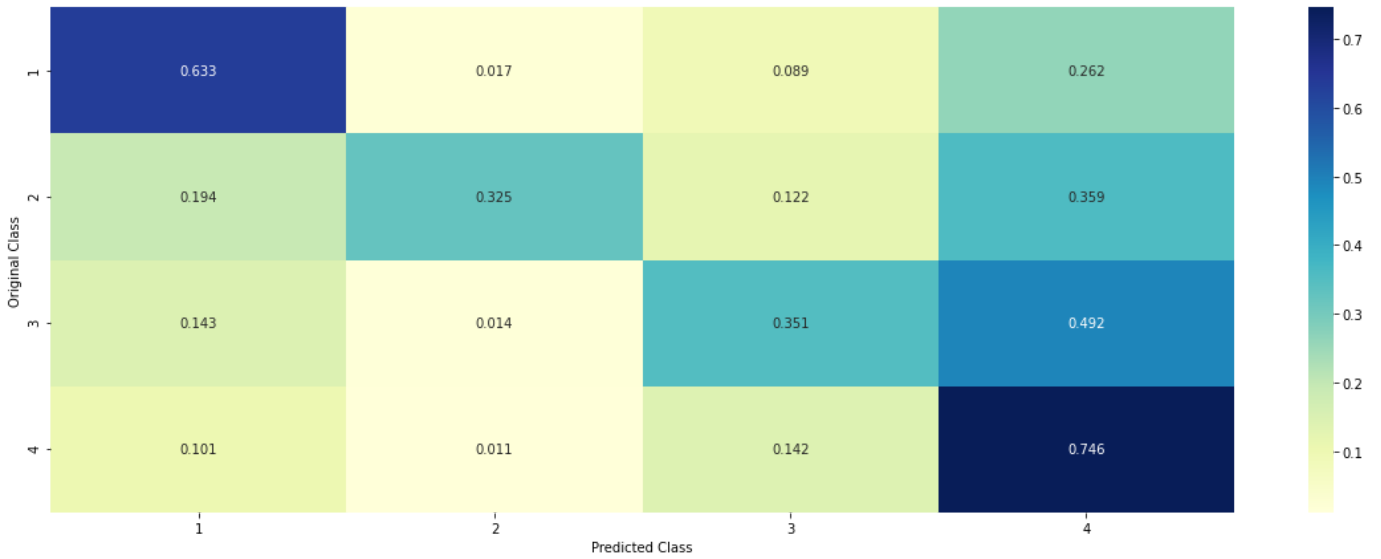

```
**************************************************
Train F1 score at 2000 is  :0.9975734530666492
**************************************************
test F1 score at 2000 is :0.5369701393349094
-------------------- Confusion matrix --------------------
```



---------- Precision matrix (Columm Sum=1) ----------

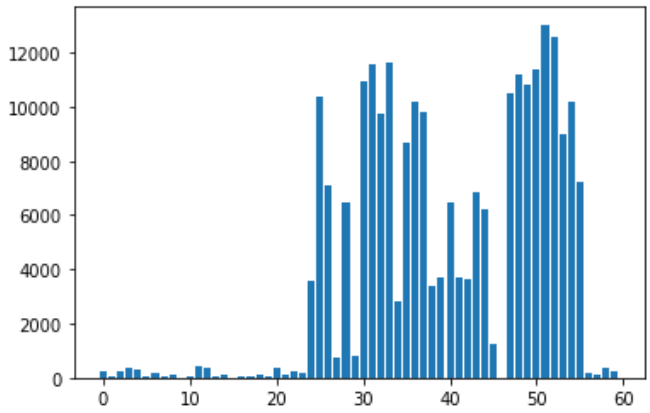


---------- Recall matrix (Row sum=1) ----------



In [42]:
```
importance = model.feature_importances_
```

In [43]:
```
importance = model.feature_importances_
plt.bar([x for x in range(len(importance))], importance)
plt.show()
```



In [ ]:
```

```

1.3.7. XGBoost (Original features)

In [44]:
```
learning_rate=[0.00001,0.0001,0.001,0.01,0.1,1,10]

f1_scores = []
for i in learning_rate:
    model = None
    model = xgb.XGBClassifier(learning_rate=i,class_weight='balanced')
    k_fold_score = kfold(5,model,train,y_train)
    f1_scores.append(k_fold_score)
    print("Macro F1 score at learning_rate={} is {} ".format(i,k_fold_score))



print("*"*50)
plt.plot(learning_rate,f1_scores,color="darkblue")

plt.grid()
plt.title("Cross Validation F1 score for each learning_rate")
plt.xlabel("hyper parameter (learning_rate)")
plt.ylabel("F1 score")
plt.show()

best_n = learning_rate[np.argmax(f1_scores)]


model = None
model = xgb.XGBClassifier(learning_rate=best_n,class_weight='balanced')
model.fit(train,y_train)


print("*"*50)
print("Train F1 score at {} is  :{} ".format(best_n, f1_score(y_train,model.predict(train),labels=model.cl
print("*"*50)
print("test F1 score at {} is :{} ".format(best_n, f1_score(y_test,model.predict(test),labels=model.classe


#plotting confusion matrix

predicted = model.predict(test)
plot_confusion_matrix(y_test,predicted)
```

```
[10:59:15] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[10:59:16] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061:
Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was
changed from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behav
ior.
[10:59:33] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[10:59:33] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061:
Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was
changed from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behav
ior.
[10:59:48] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[10:59:48] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061:
Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was
changed from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behav
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ior.
[11:00:04] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:00:04] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061:
Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was
changed from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behav
ior.
[11:00:19] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:00:19] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061:
Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was
changed from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behav
ior.
Macro F1 score at learning_rate=1e-05 is 0.32471130138756255
[11:00:35] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:00:35] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061:
Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was
changed from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behav
ior.
[11:00:51] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:00:51] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061:
Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was
changed from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behav
ior.
[11:01:06] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:01:07] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061:
Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was
changed from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behav
ior.
[11:01:22] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:01:22] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061:
Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was
changed from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behav
ior.
[11:01:37] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.
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  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:01:37] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061:
Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was
changed from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behav
ior.
Macro F1 score at learning_rate=0.0001 is 0.32460935268781926
[11:01:53] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:01:53] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061:
Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was
changed from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behav
ior.
[11:02:09] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:02:09] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061:
Starting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was
changed from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behav
ior.
[11:02:24] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:02:24] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[11:02:40] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:02:40] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[11:02:55] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:02:56] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
Macro F1 score at learning_rate=0.001 is 0.32547760924059277
[11:03:11] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.
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[11:03:11] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[11:03:27] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:03:27] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[11:03:42] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:03:42] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[11:03:59] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:03:59] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[11:04:15] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:04:15] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
Macro F1 score at learning_rate=0.01 is 0.32722619510496054
[11:04:31] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:04:31] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[11:04:46] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:04:46] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[11:05:02] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.
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[11:05:02] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[11:05:18] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.



[11:05:18] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[11:05:33] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:05:33] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
Macro F1 score at learning_rate=0.1 is 0.37311141989163904
[11:05:48] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:05:49] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[11:06:04] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:06:04] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[11:06:20] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:06:20] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[11:06:36] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:06:36] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[11:06:51] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
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  verification. Please open an issue if you find above cases.


[11:06:51] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
Macro F1 score at learning_rate=1 is 0.49615418093204794
[11:07:07] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:07:07] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[11:07:09] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:07:10] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[11:07:13] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:07:13] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[11:07:16] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:07:16] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[11:07:18] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:07:19] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
Macro F1 score at learning_rate=10 is 0.1891047203385102
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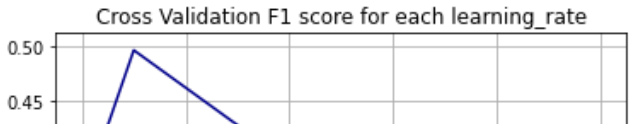


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[11:07:21] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:07:22] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
**************************************************
Train F1 score at 1 is  :0.9484680258119806
**************************************************
test F1 score at 1 is :0.5149071045702365
-------------------- Confusion matrix --------------------
```
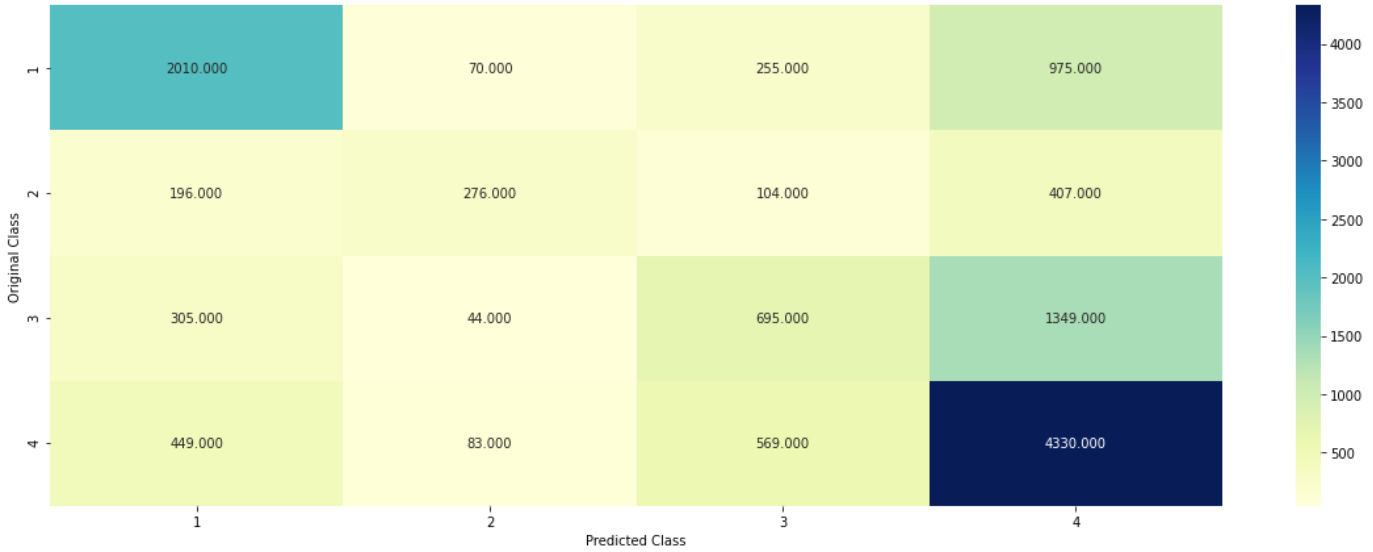
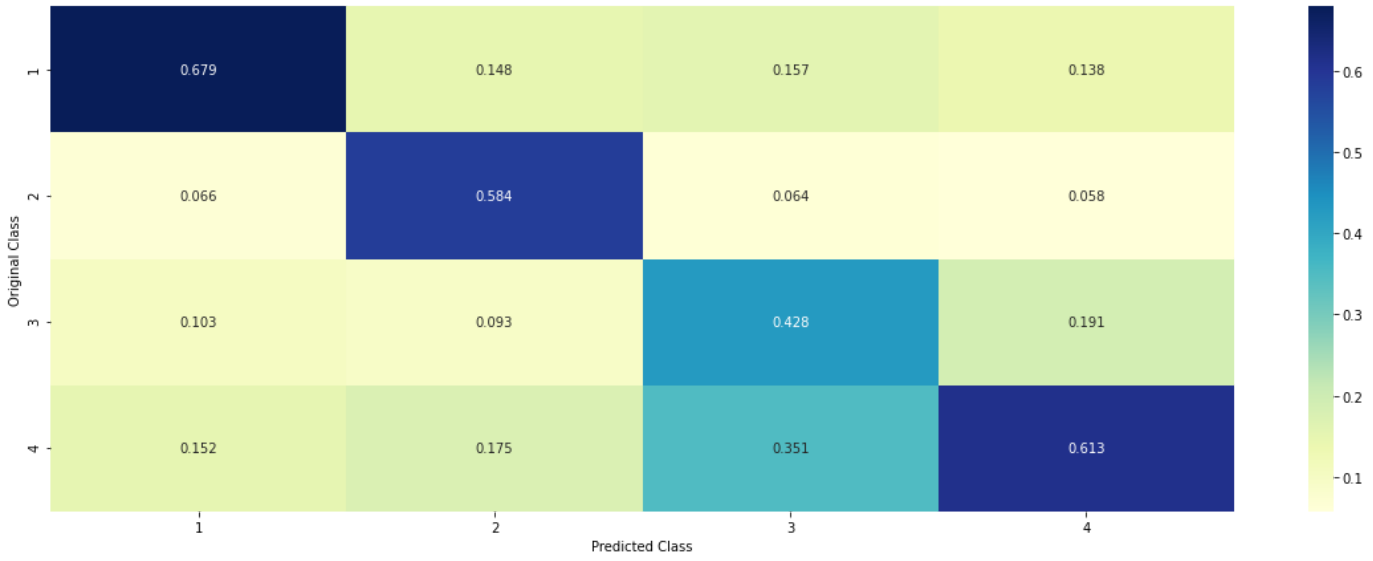
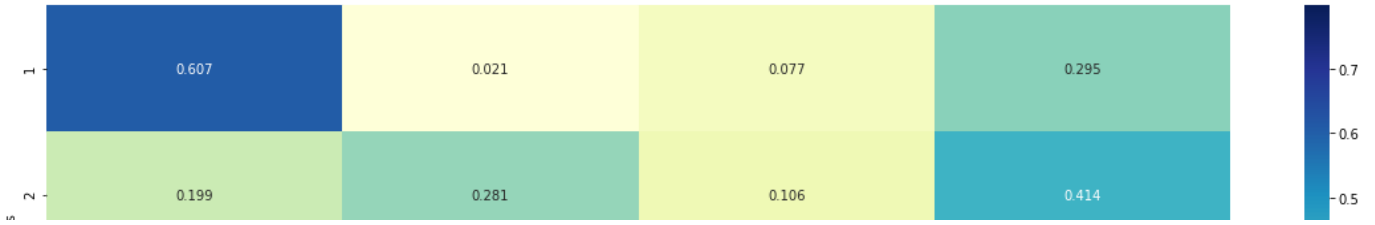




```
-------------------- Precision matrix (Columm Sum=1) --------------------
```




```
-------------------- Recall matrix (Row sum=1) --------------------
```



XGBoost with fine hyperparameter tuning

In [45]:
```
param_grid = {
    'max_depth': [2,3,4,5,6,7,8],
    'learning_rate': [0.001, 0.01, 0.1, 0.2, 0.3],
    'n_estimators': [5,10,50,100,200,250]}

clf = xgb.XGBClassifier(n_jobs=-1 ,early_stopping_rounds = 10, eta = 0.02,class_weight='balanced')
random_search = RandomizedSearchCV(clf, param_grid, n_iter=30,n_jobs=-1,scoring="f1_macro", verbose=1, cv=
random_search.fit(train, y_train)
```

```
Fitting 5 folds for each of 30 candidates, totalling 150 fits
```

Out[45]:
```
RandomizedSearchCV(cv=5,
                   estimator=XGBClassifier(base_score=None, booster=None,
                                           class_weight='balanced',
                                           colsample_bylevel=None,
                                           colsample_bynode=None,
                                           colsample_bytree=None,
                                           early_stopping_rounds=10, eta=0.02,
                                           gamma=None, gpu_id=None,
                                           importance_type='gain',
                                           interaction_constraints=None,
                                           learning_rate=None,
                                           max_delta_step=None, max_depth=None,
                                           min_child_weight=No...
                                           num_parallel_tree=None,
                                           random_state=None, reg_alpha=None,
                                           reg_lambda=None,
                                           scale_pos_weight=None,
                                           subsample=None, tree_method=None,
                                           validate_parameters=None,
                                           verbosity=None),
                   n_iter=30, n_jobs=-1,
                   param_distributions={'learning_rate': [0.001, 0.01, 0.1, 0.2,
                                                          0.3],
                                        'max_depth': [2, 3, 4, 5, 6, 7, 8],
                                        'n_estimators': [5, 10, 50, 100, 200,
                                                         250]},
                   random_state=42, refit=False, scoring='f1_macro', verbose=1)
```

In [ ]:
```
```

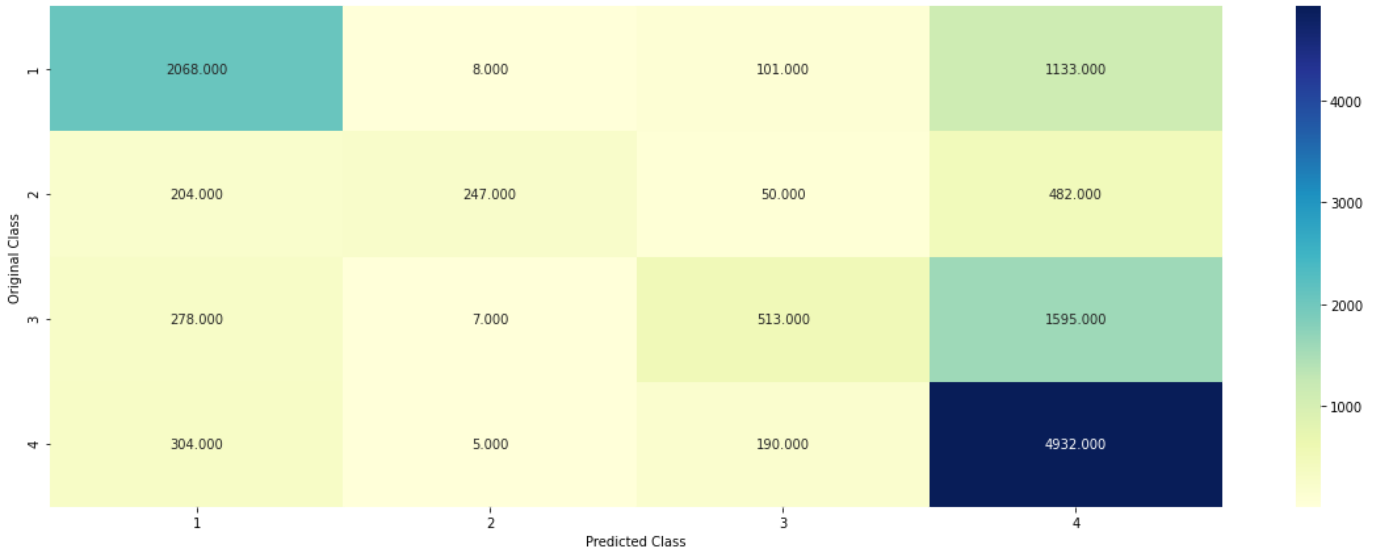
In [46]:
```
params = random_search.best_params_
```

In [47]:
```
params
```

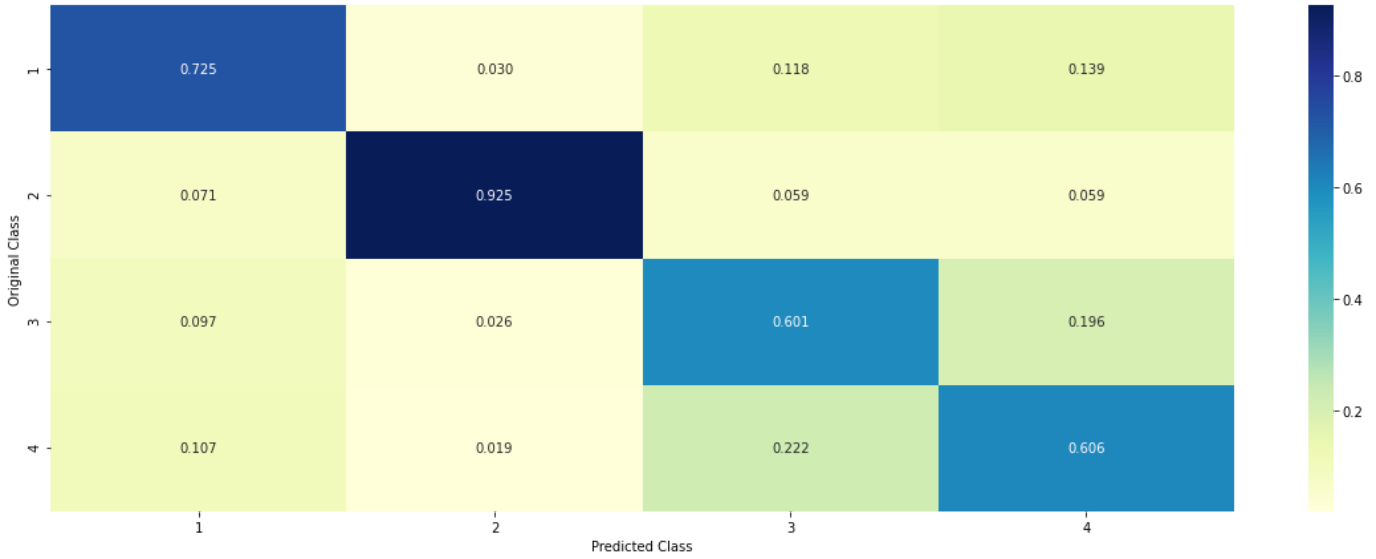
Out[47]:
```
{'n_estimators': 100, 'max_depth': 8, 'learning_rate': 0.3}
```

In [48]:
```
clf = xgb.XGBClassifier(n_estimators= params["n_estimators"], max_depth= params["max_depth"],
                        learning_rate= params["learning_rate"]  ,early_stopping_rounds = 10,eta = 0.02,cla

clf.fit(train,y_train)

pred_test = clf.predict(test)
pred_train = clf.predict(train)

print("Train F1 score is  :{} ".format(f1_score(y_train,pred_train,labels=[1,2,3,4],average="macro")))
print("*"*50)
print("test F1 score is :{} ".format(f1_score(y_test,pred_test,labels=[1,2,3,4],average="macro")))

plot_confusion_matrix(y_test,pred_test)
```

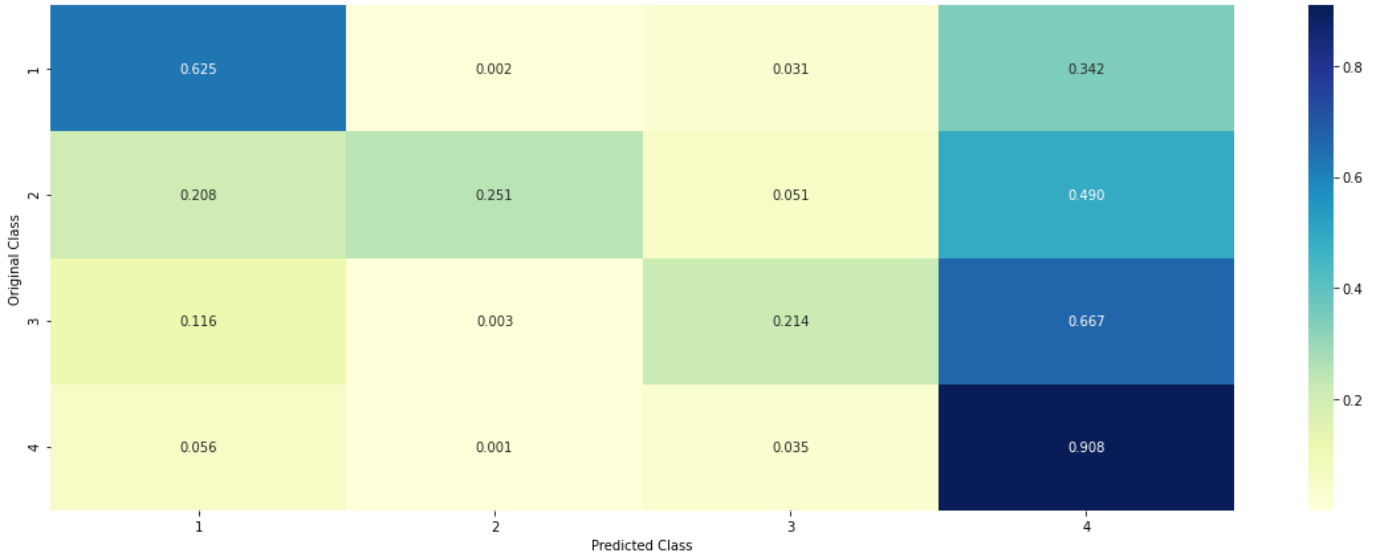
```
[11:35:18] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:541:
Parameters: { class_weight, early_stopping_rounds } might not be used.

  This may not be accurate due to some parameters are only used in language bindings but
  passed down to XGBoost core.  Or some parameters are not used but slip through this
  verification. Please open an issue if you find above cases.


[11:35:19] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
Train F1 score is  :0.8802419943531
**************************************************
test F1 score is :0.5272284377857827
-------------------- Confusion matrix --------------------
```




```
-------------------- Precision matrix (Columm Sum=1) --------------------
```




```
-------------------- Recall matrix (Row sum=1) --------------------
```



1.4 Random Over Sampling

In [49]:
```
from imblearn.over_sampling import RandomOverSampler
from imblearn.under_sampling import RandomUnderSampler
```

In [50]:
```
om = RandomOverSampler(random_state=10)
x_res , y_res = om.fit_resample(train_features,y_train)
```

In [51]:
```
x_res.shape
```

Out[51]:
```
(65176, 60)
```

In [52]:
```
print("class distribution BEFORE SMOTE in train data: \n",y_train.value_counts())
print("class distribution AFTER SMOTE in train data: \n",y_res.value_counts())
```

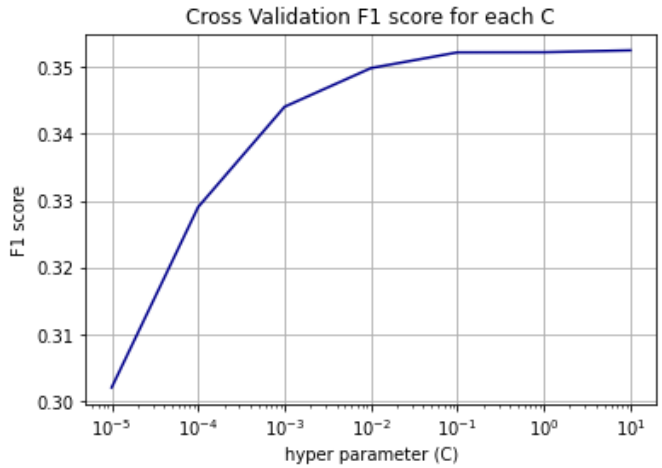
```
class distribution BEFORE SMOTE in train data:
 4    16294
1     9931
3     7180
2     2946
Name: review_score, dtype: int64
class distribution AFTER SMOTE in train data:
 1    16294
3    16294
4    16294
2    16294
Name: review_score, dtype: int64
```

In [53]:
```
def kfold_sampling(k,model):
    """This function will do stratified k-fold cross_validation"""
    kf = StratifiedKFold(n_splits=k)

    cv_f1_score = []
    for tr_ind,cv_ind in kf.split(x_res,y_res):

        x_tr,x_cv,y_tr,y_cv = x_res[tr_ind],x_res[cv_ind],y_res[tr_ind],y_res[cv_ind]

        model.fit(x_tr,y_tr)
        pred_cv = model.predict(x_cv)
        cv_f1_score.append((f1_score(y_cv,pred_cv,average="macro",labels=[1,2,3,4])))

    return np.mean(cv_f1_score)
```

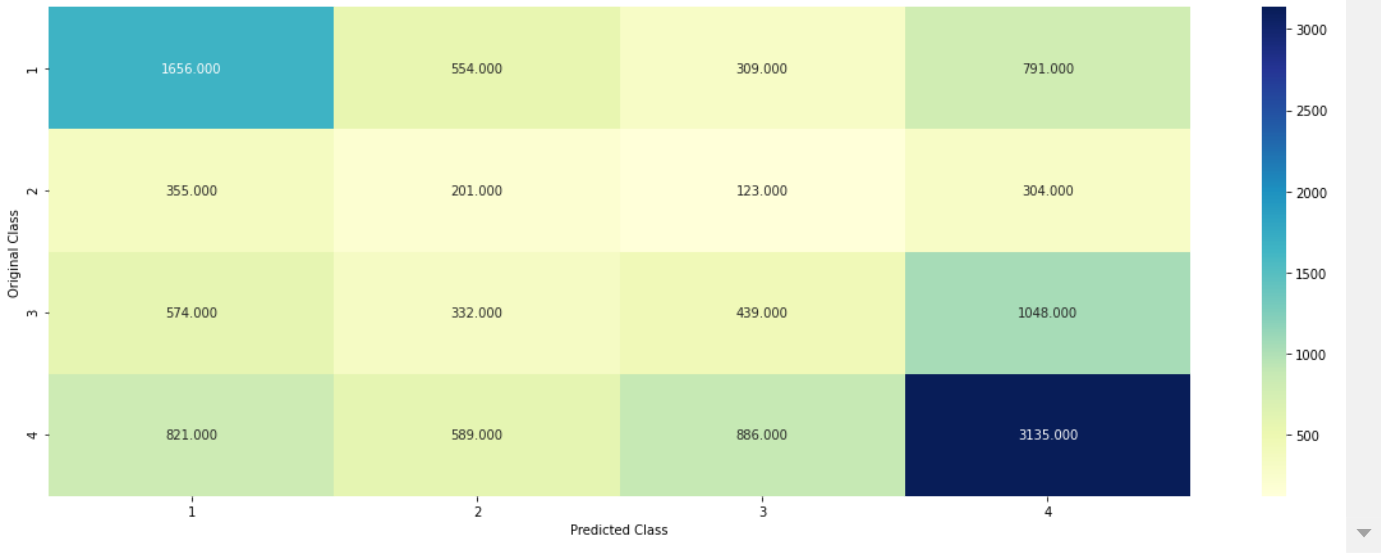
1.4.1 Logistic Regression:

In [54]:
```
C=[0.00001,0.0001,0.001,0.01,0.1,1,10]

f1_scores = []
for i in C:
    model = None
    model = LogisticRegression(C=i)
    k_fold_score = kfold_sampling(5,model)
    f1_scores.append(k_fold_score)
    print("Macro F1 score at C={} is {} ".format(i,k_fold_score))



print("*"*50)
plt.plot(C,f1_scores,color="darkblue")
plt.xscale("log")
plt.grid()
plt.title("Cross Validation F1 score for each C")
plt.xlabel("hyper parameter (C)")
plt.ylabel("F1 score")
plt.show()

best_param = C[np.argmax(f1_scores)]

model = None
model = LogisticRegression(C=i)
model.fit(x_res,y_res)


print("*"*50)
print("Train F1 score at {} is :{}".format(best_param, f1_score(y_res,model.predict(x_res),labels=model.cl
print("*"*50)
print("test F1 score at {} is :{}".format(best_param, f1_score(y_test,model.predict(test_features),labels=

#plotting confusion matrix
predicted = model.predict(test_features)
plot_confusion_matrix(y_test,predicted)
```

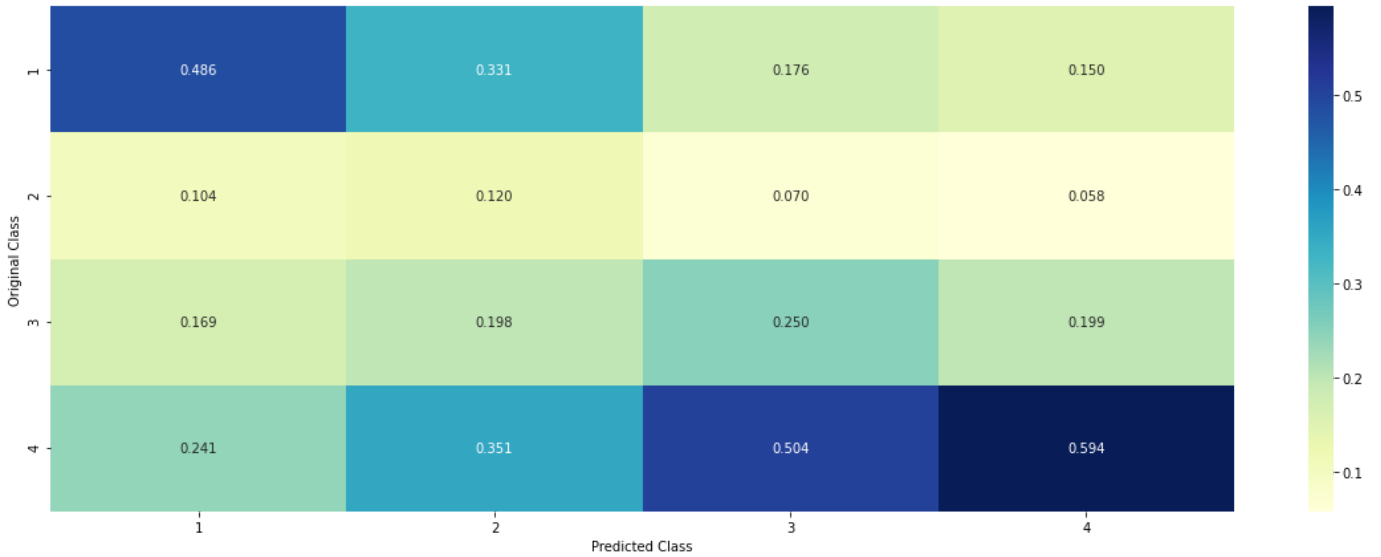
```
Macro F1 score at C=1e-05 is 0.302074131236081
Macro F1 score at C=0.0001 is 0.3290341658275457
Macro F1 score at C=0.001 is 0.34402585966578497
Macro F1 score at C=0.01 is 0.3498104380134787
Macro F1 score at C=0.1 is 0.3521571193367433
Macro F1 score at C=1 is 0.35217567538409694
Macro F1 score at C=10 is 0.352461370786819
**************************************************
```



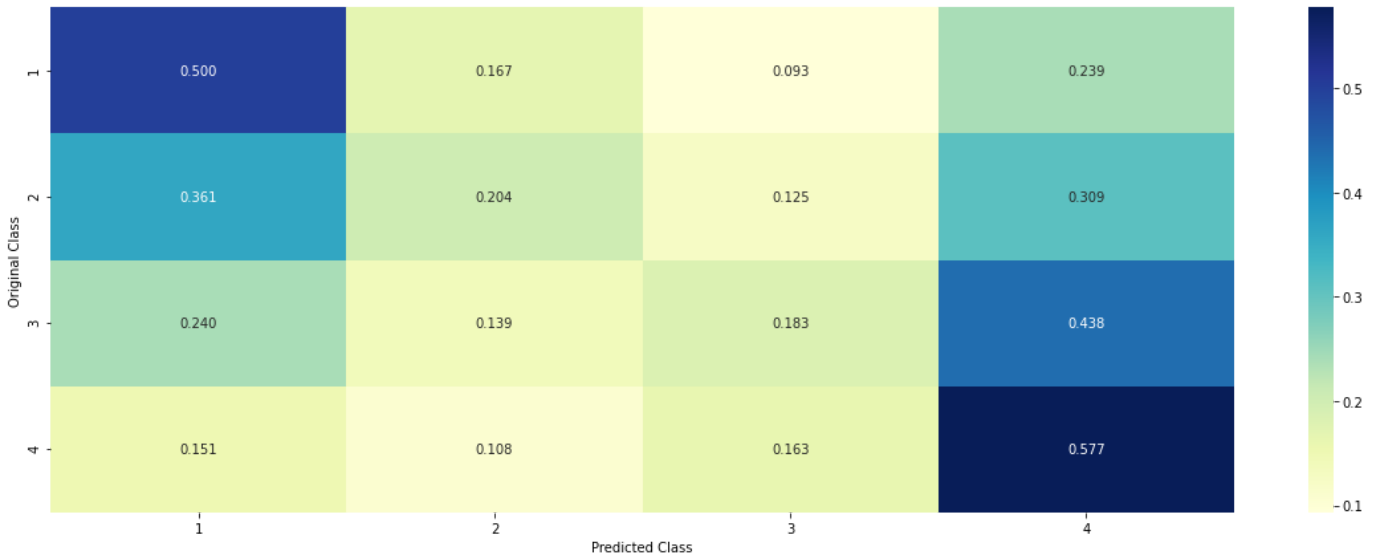

```
**************************************************
Train F1 score at 10 is :0.3541984230508761
**************************************************
test F1 score at 10 is :0.3603476117597647
-------------------- Confusion matrix --------------------
```



---------- Precision matrix (Columm Sum=1) ----------



---------- Recall matrix (Row sum=1) ----------



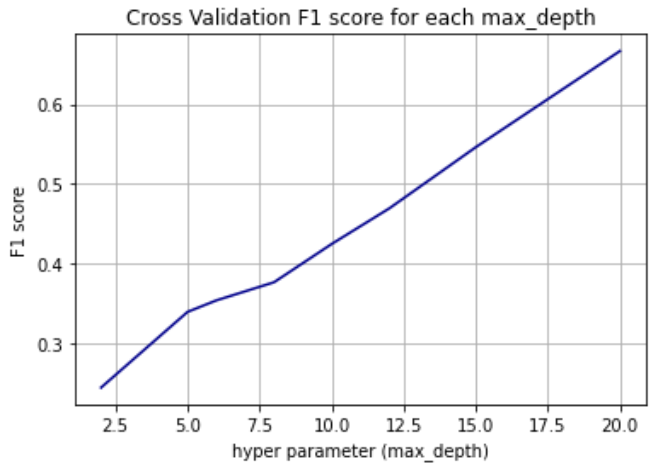
In [ ]:

In [ ]:

1.4.2. Decision Tree

In [55]:
```
max_depth=[2,5,6,8,10,12,15,20]

f1_scores = []
for i in max_depth:
    model = None
    model = DecisionTreeClassifier(max_depth=i)
    k_fold_score = kfold_sampling(5,model)
    f1_scores.append(k_fold_score)
    print("Macro F1 score at n={} is {} ".format(i,k_fold_score))



print("*"*50)
plt.plot(max_depth,f1_scores,color="darkblue")

plt.grid()
plt.title("Cross Validation F1 score for each max_depth")
plt.xlabel("hyper parameter (max_depth)")
plt.ylabel("F1 score")
plt.show()

best_param = max_depth[np.argmax(f1_scores)]

model = None
model = DecisionTreeClassifier(max_depth=best_param)
model.fit(x_res,y_res)


print("*"*50)
print("Train F1 score at {} is :{}".format(best_param, f1_score(y_res,model.predict(x_res),labels=model.cl
print("*"*50)
print("test F1 score at {} is :{}".format(best_param, f1_score(y_test,model.predict(test_features),labels=

#plotting confusion matrix
predicted = model.predict(test_features)
plot_confusion_matrix(y_test,predicted)
```

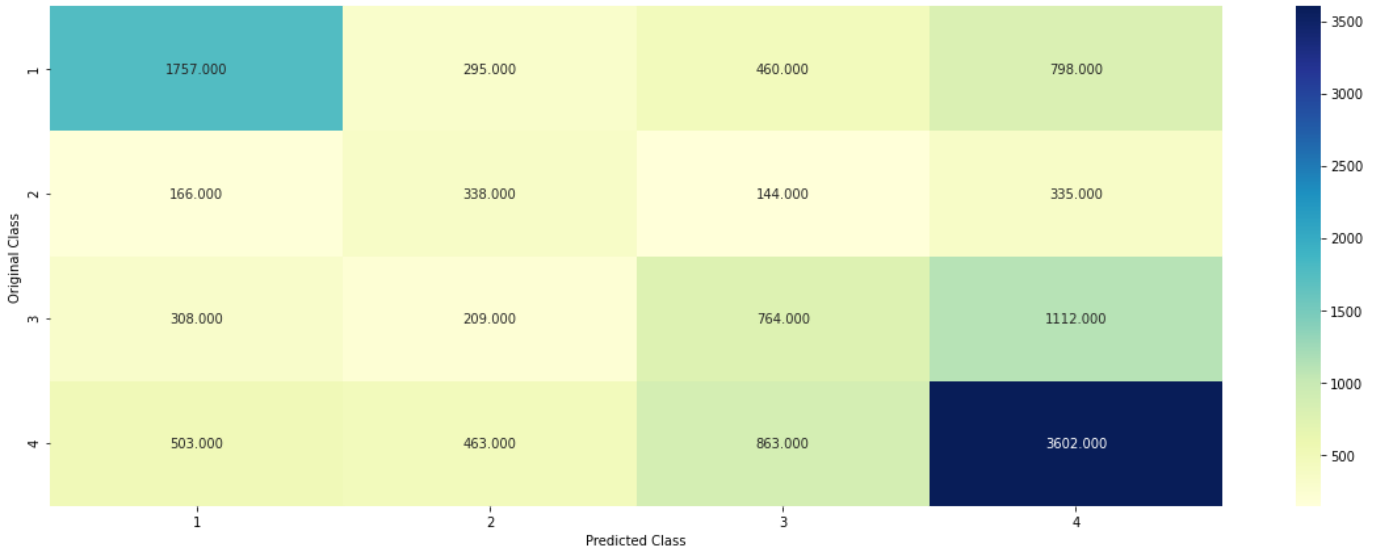
```
Macro F1 score at n=2 is 0.24382369991778777
Macro F1 score at n=5 is 0.3389760034415418
Macro F1 score at n=6 is 0.35346378660162986
Macro F1 score at n=8 is 0.3762400697250904
Macro F1 score at n=10 is 0.42435985068977916
Macro F1 score at n=12 is 0.46914171296168466
Macro F1 score at n=15 is 0.5460621833268051
Macro F1 score at n=20 is 0.6669306969768977
**************************************************
```



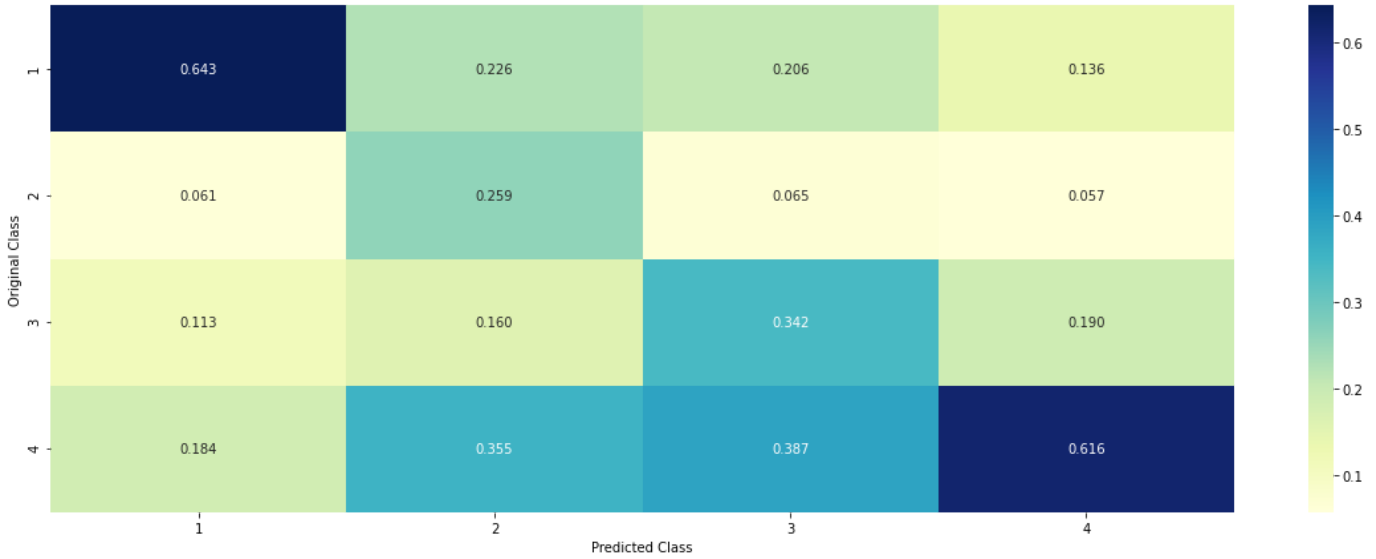

```
**************************************************
Train F1 score at 20 is :0.7634176613138941
**************************************************
```

test F1 score at 20 is :0.4615182888479491

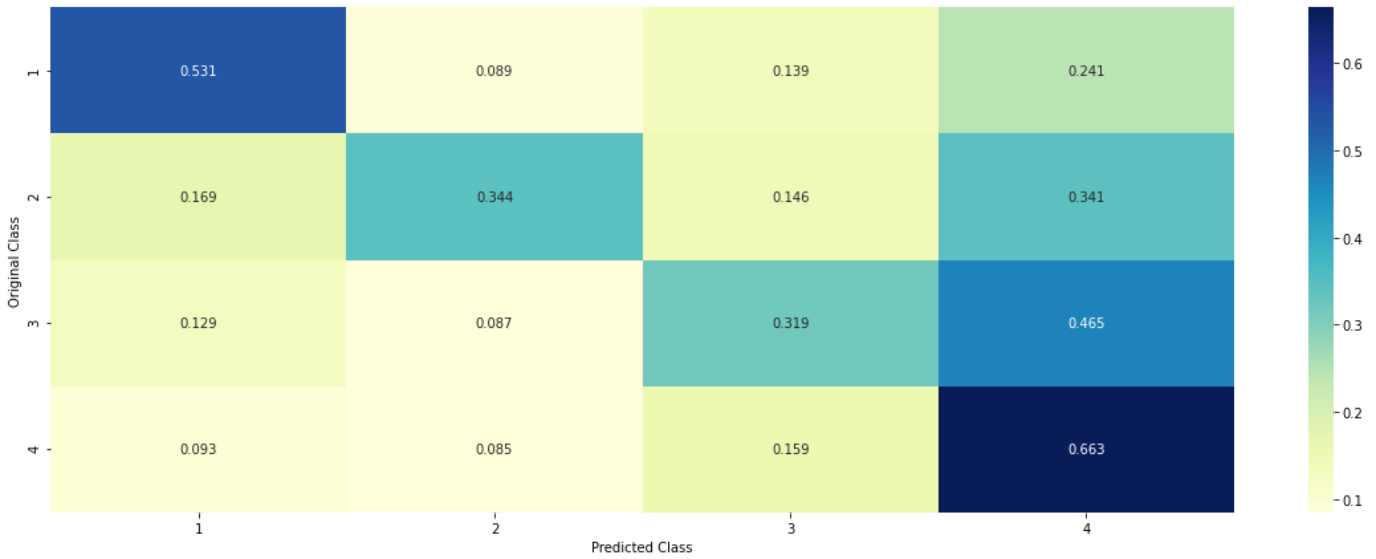
---------- Confusion matrix ----------



---------- Precision matrix (Columm Sum=1) ----------



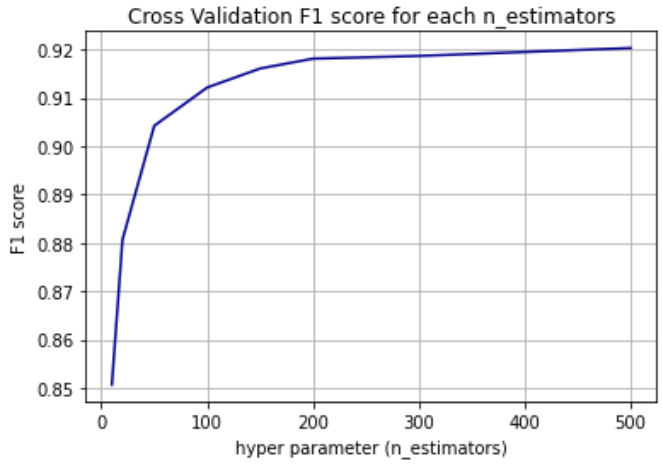
---------- Recall matrix (Row sum=1) ----------



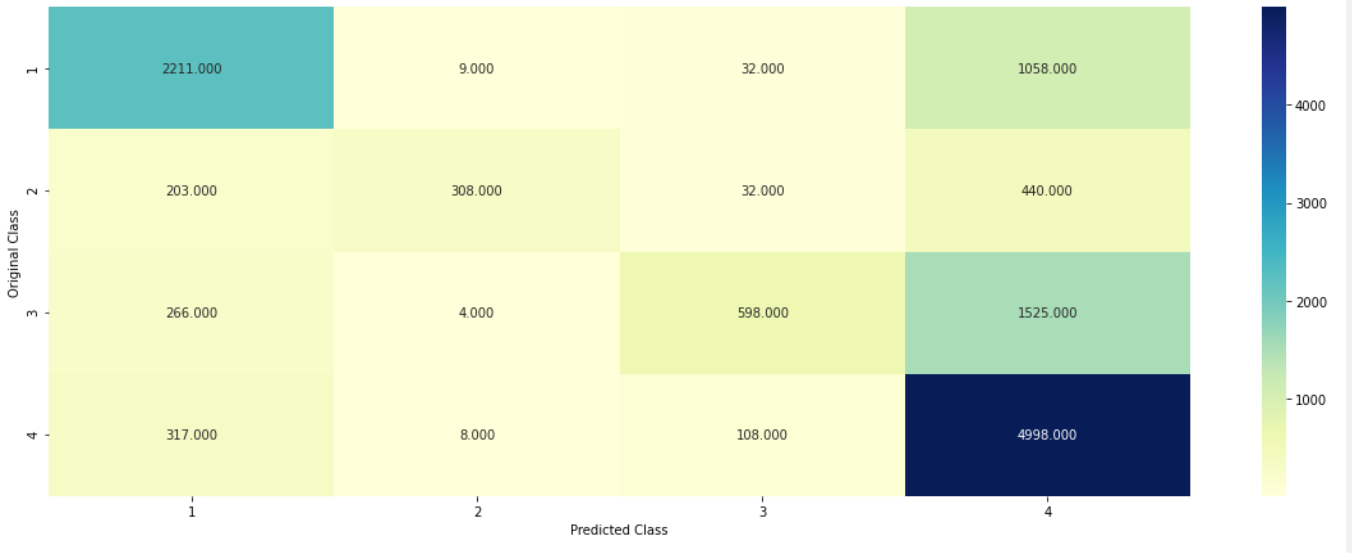
RF

In [56]:
```
n_estimators=[10,20,50,100,150,200,300,500]


f1_scores = []
for i in n_estimators:
    model = None
    model = RandomForestClassifier(n_estimators=i)
    k_fold_score = kfold_sampling(5,model)
    f1_scores.append(k_fold_score)
    print("Macro F1 score at n={} is {} ".format(i,k_fold_score))



print("*"*50)
plt.plot(n_estimators,f1_scores,color="darkblue")

plt.grid()
plt.title("Cross Validation F1 score for each n_estimators")
plt.xlabel("hyper parameter (n_estimators)")
plt.ylabel("F1 score")
plt.show()

best_param = n_estimators[np.argmax(f1_scores)]

model = None
model = RandomForestClassifier(n_estimators=best_param)
model.fit(x_res,y_res)


print("*"*50)
print("Train F1 score at {} is :{}".format(best_param, f1_score(y_res,model.predict(x_res),labels=model.cl
print("*"*50)
print("test F1 score at {} is :{}".format(best_param, f1_score(y_test,model.predict(test_features),labels=

#plotting confusion matrix
predicted = model.predict(test_features)
plot_confusion_matrix(y_test,predicted)
```

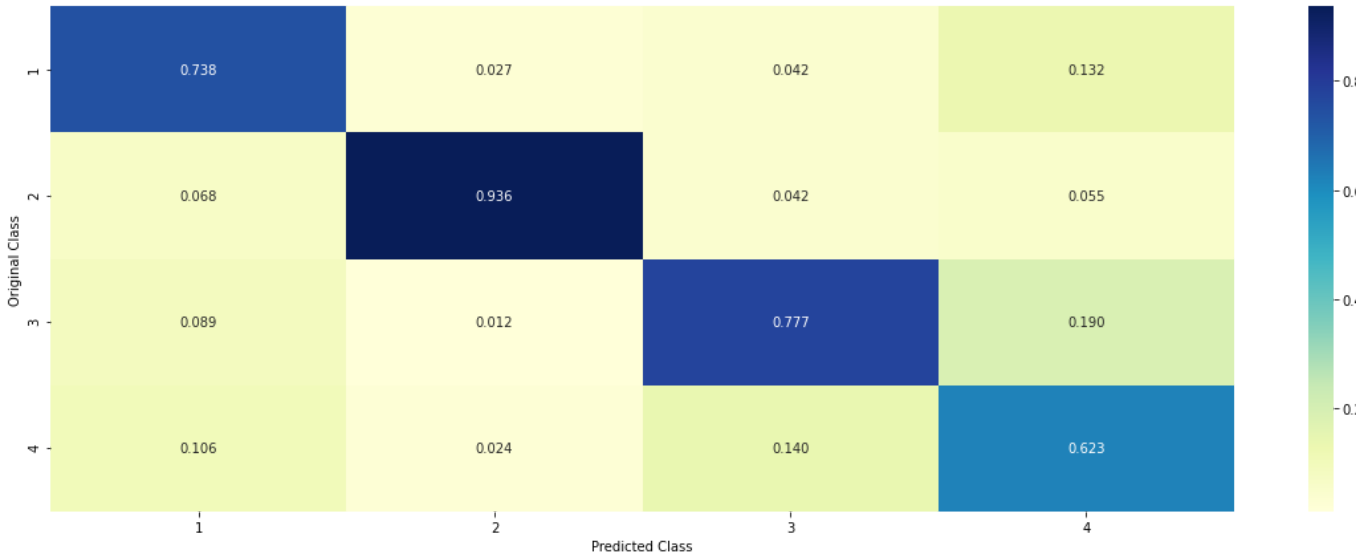
```
Macro F1 score at n=10 is 0.8506991868226434
Macro F1 score at n=20 is 0.8806786852704456
Macro F1 score at n=50 is 0.904239376312829
Macro F1 score at n=100 is 0.9121565104552504
Macro F1 score at n=150 is 0.9160924963700889
Macro F1 score at n=200 is 0.918129771421191
Macro F1 score at n=300 is 0.9186937492421705
Macro F1 score at n=500 is 0.920323616321195
**************************************************
```



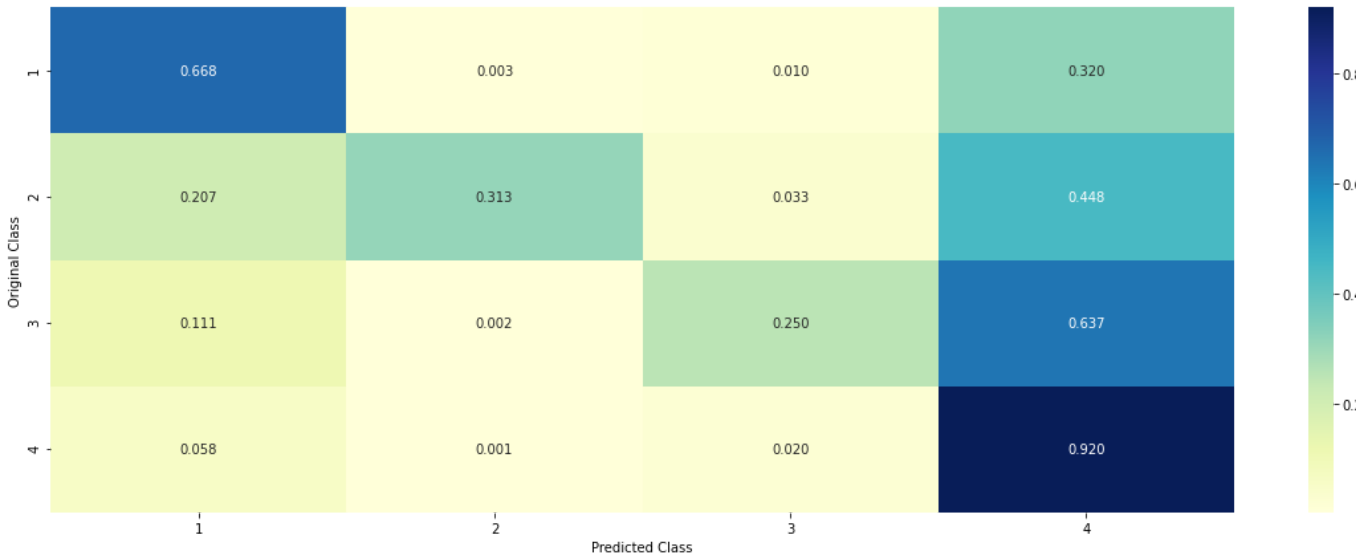

```
**************************************************
Train F1 score at 500 is :0.9987572938141489
**************************************************
test F1 score at 500 is :0.5729616235899773
-------------------- Confusion matrix --------------------
```



---------- Precision matrix (Columm Sum=1) ----------



---------- Recall matrix (Row sum=1) ----------



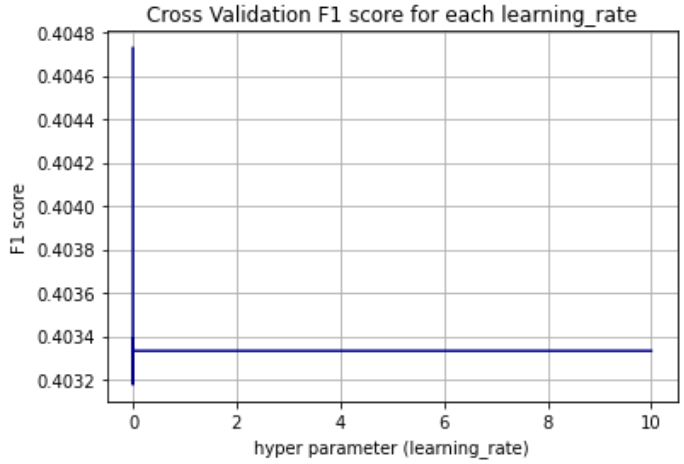
XGBRF model

In [57]:
```
learning_rate=[0.00001,0.0001,0.001,0.01,0.1,1,10]

f1_scores = []
for i in learning_rate:
    model = None
    model = xgb.XGBRFClassifier(learning_rate=i)
    k_fold_score = kfold_sampling(5,model)
    f1_scores.append(k_fold_score)
    print("Macro F1 score at learning_rate={} is {} ".format(i,k_fold_score))



print("*"*50)
plt.plot(learning_rate,f1_scores,color="darkblue")

plt.grid()
plt.title("Cross Validation F1 score for each learning_rate")
plt.xlabel("hyper parameter (learning_rate)")
plt.ylabel("F1 score")
plt.show()

best_n = learning_rate[np.argmax(f1_scores)]


model = None
model = xgb.XGBRFClassifier(learning_rate=best_n)
model.fit(x_res,y_res)


print("*"*50)
print("Train F1 score at {} is  :{} ".format(best_n, f1_score(y_res,model.predict(x_res),labels=model.clas
print("*"*50)
print("test F1 score at {} is :{} ".format(best_n, f1_score(y_test,model.predict(test_features),labels=mod


#plotting confusion matrix

predicted = model.predict(test_features)
plot_confusion_matrix(y_test,predicted)
```

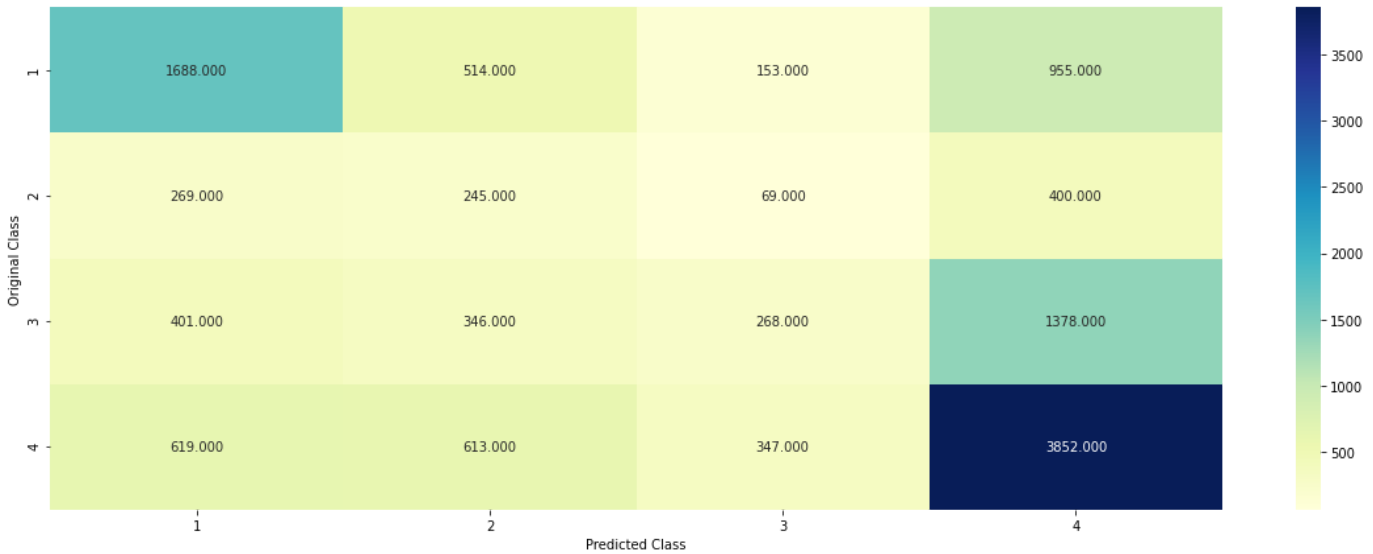
```
[12:13:24] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:13:59] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:14:37] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:15:14] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:15:53] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
Macro F1 score at learning_rate=1e-05 is 0.40472720707842946
[12:16:30] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:17:07] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:17:45] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:18:22] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:18:58] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
Macro F1 score at learning_rate=0.0001 is 0.40317649327011756
[12:19:33] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
```

```
[12:20:11] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:20:48] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:21:26] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:22:04] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
Macro F1 score at learning_rate=0.001 is 0.4033903012665153
[12:22:40] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:23:17] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:23:55] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:24:32] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:25:10] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
Macro F1 score at learning_rate=0.01 is 0.40333196858986253
[12:25:47] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:26:24] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:27:02] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:27:40] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:28:17] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
Macro F1 score at learning_rate=0.1 is 0.40333206636318614
[12:28:55] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.

[12:29:32] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:30:09] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:30:47] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:31:25] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
Macro F1 score at learning_rate=1 is 0.40333206636318614
[12:32:03] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:32:40] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:33:18] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:33:56] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
[12:34:34] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
```

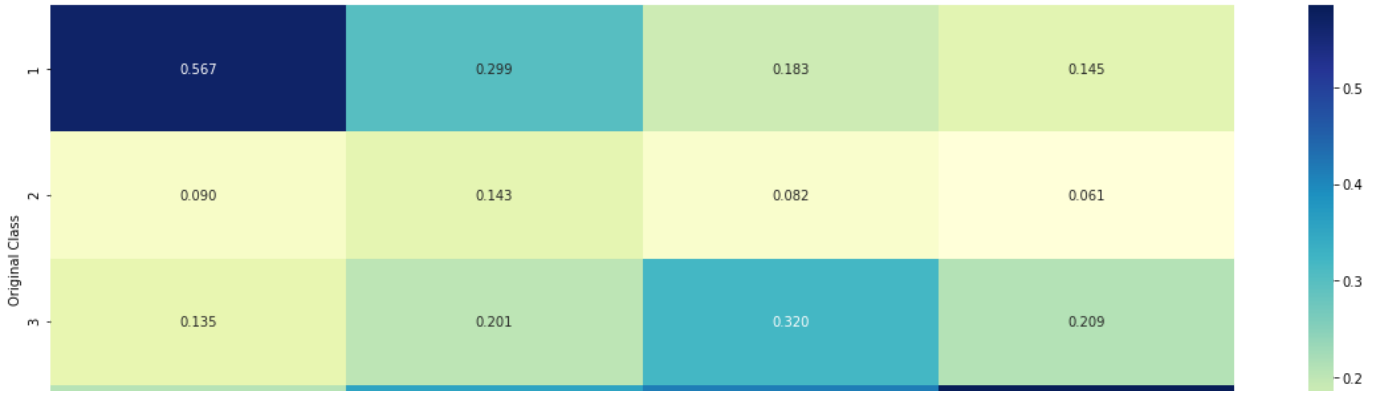
```
Macro F1 score at learning_rate=10 is 0.40333206636318614
**************************************************
```



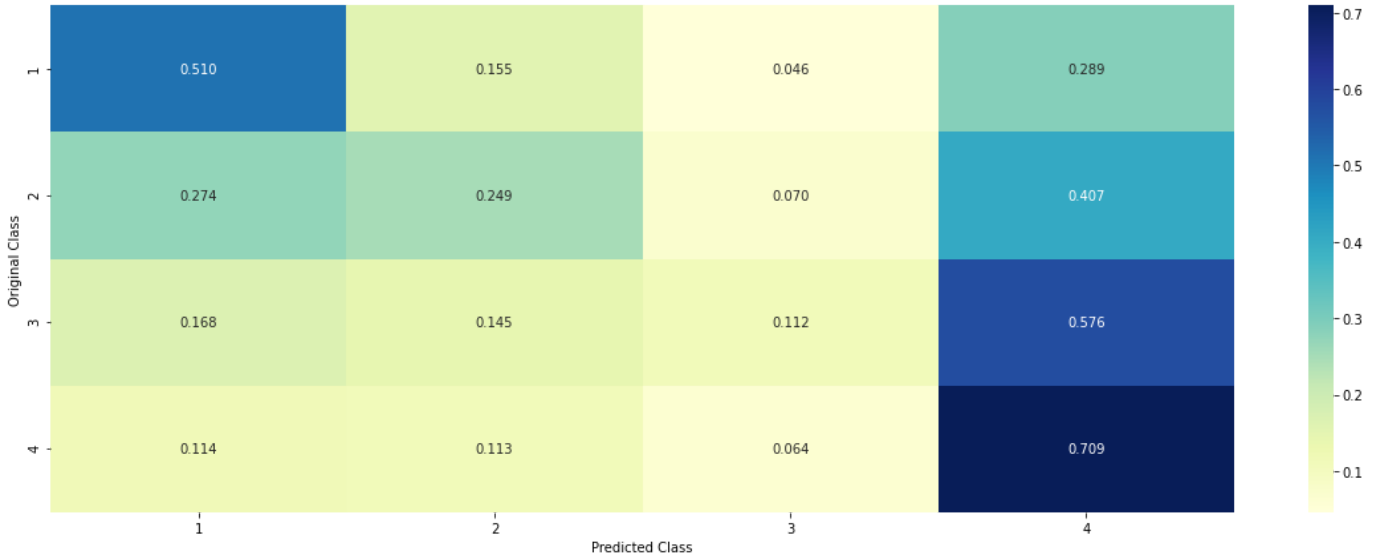

```
[12:35:19] WARNING: C:/Users/Administrator/workspace/xgboost-win64_release_1.3.0/src/learner.cc:1061: St
arting in XGBoost 1.3.0, the default evaluation metric used with the objective 'multi:softprob' was chan
ged from 'merror' to 'mlogloss'. Explicitly set eval_metric if you'd like to restore the old behavior.
**************************************************
Train F1 score at 1e-05 is  :0.42279092545950353
**************************************************
test F1 score at 1e-05 is :0.3813711938290445
-------------------- Confusion matrix --------------------
```




```
-------------------- Precision matrix (Columm Sum=1) --------------------
```



---------- Recall matrix (Row sum=1) ----------



In [ ]:

In [ ]:

1.4.3. LGBM

In [58]:
```
param_grid = {
    'learning_rate': [0.001, 0.01, 0.1, 0.2],
    'n_estimators': [5,10,50,100,200,250]}

clf = lgb.LGBMClassifier(n_jobs=-1,boosting_type="goss")
random_search = RandomizedSearchCV(clf, param_grid, n_iter=30,n_jobs=-1,scoring="f1_macro",
                                   verbose=1, cv=5, refit=False, random_state=42)
random_search.fit(x_res, y_res)
```

```
Fitting 5 folds for each of 24 candidates, totalling 120 fits
```

Out[58]:
```
RandomizedSearchCV(cv=5, estimator=LGBMClassifier(boosting_type='goss'),
                   n_iter=30, n_jobs=-1,
                   param_distributions={'learning_rate': [0.001, 0.01, 0.1,
                                                          0.2],
                                        'n_estimators': [5, 10, 50, 100, 200,
                                                         250]},
                   random_state=42, refit=False, scoring='f1_macro', verbose=1)
```

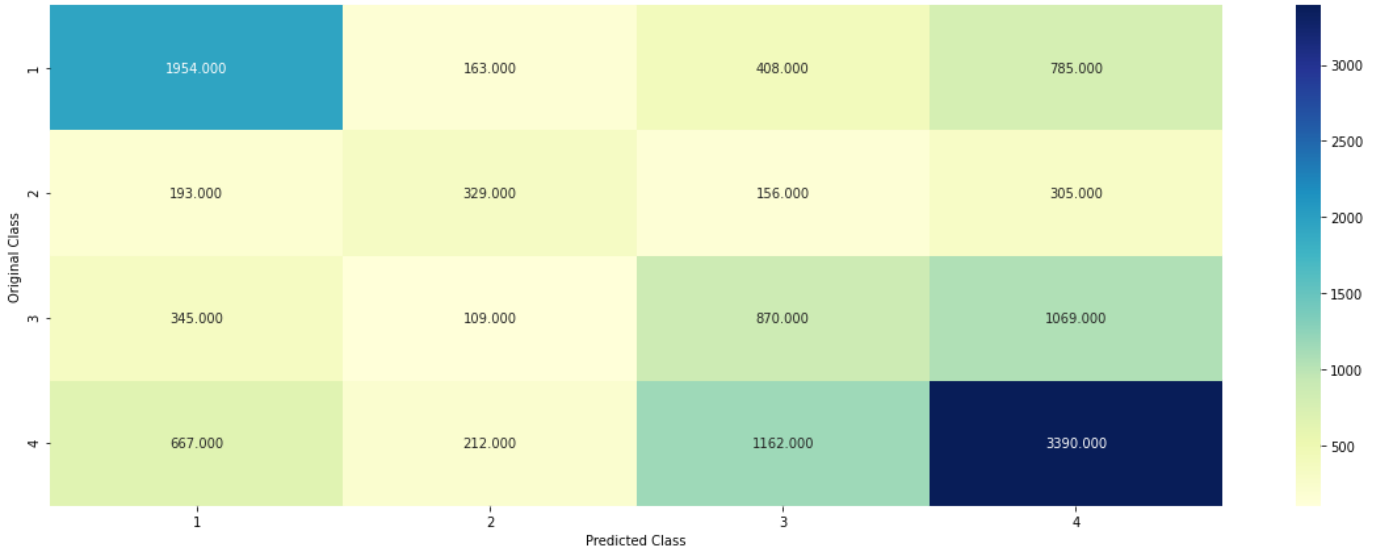
In [59]:
```
params = random_search.best_params_
```

In [60]:
```
print(params)
```

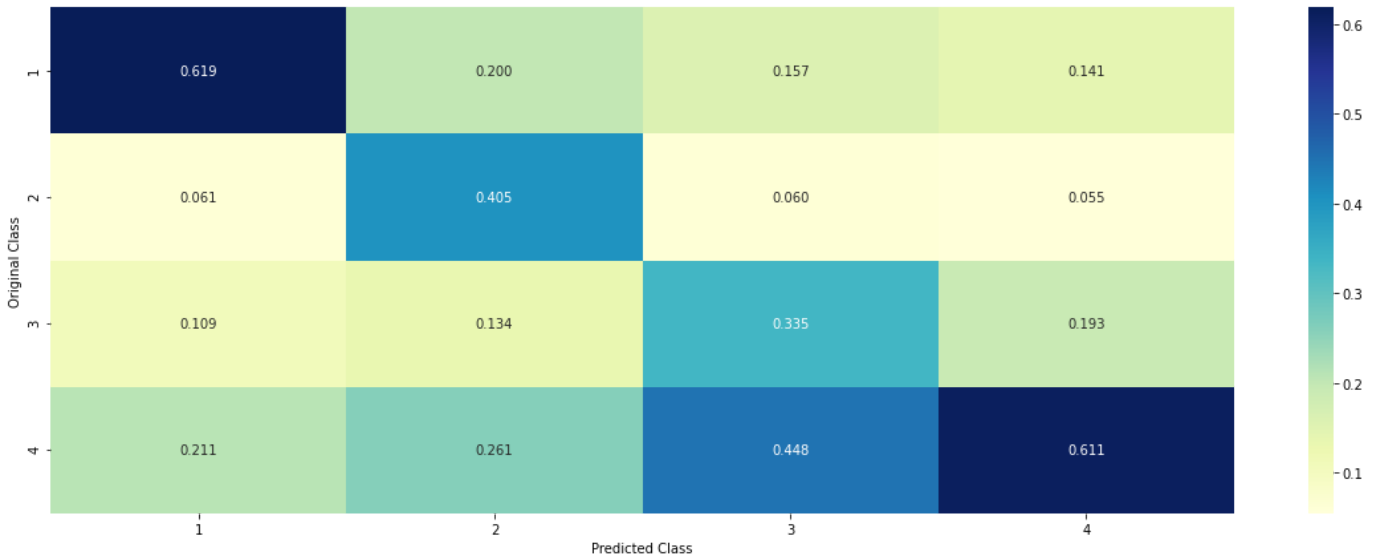
```
{'n_estimators': 250, 'learning_rate': 0.2}
```

In [61]:
```
clf = lgb.LGBMClassifier(n_estimators= params["n_estimators"],
                         boosting_type="goss",
                        learning_rate= params["learning_rate"], n_jobs=-1)
clf.fit(x_res,y_res)

pred_test = clf.predict(test_features)
pred_train = clf.predict(x_res)

print("Train F1 score is  :{} ".format(f1_score(y_res,pred_train,labels=[1,2,3,4],average="macro")))
print("*"*50)
print("test F1 score is :{} ".format(f1_score(y_test,pred_test,labels=[1,2,3,4],average="macro")))

plot_confusion_matrix(y_test,pred_test)
```

```
Train F1 score is  :0.9052961200414245
**************************************************
test F1 score is :0.48418381391979004
-------------------- Confusion matrix --------------------
```




```
-------------------- Precision matrix (Columm Sum=1) --------------------
```




```
-------------------- Recall matrix (Row sum=1) --------------------
```

In [ ]:

SUMMARY TABLE

Model	Train Macro F1 score	Test Macro F1 score
Logistic Regression	0.368	0.358
KNN	0.691	0.409
Decision Tree	0.515	0.416
Random Forest	0.997	0.553
LGBM	0.997	0.545
XGBoost	0.948	0.515
XGBoost(fine tune)	0.88	0.527

Feature selection

Model	Train Macro F1 score	Test Macro F1 score
LGBM	0.997	0.537

Random Oversampling

Model	Train Macro F1 score	Test Macro F1 score
Logistic Regression	0.354	0.360
Decision Tree	0.76	0.46
Random Forest	0.998	0.573
LGBM	0.905	0.484
XGBRF	0.42	0.38

In [ ]: