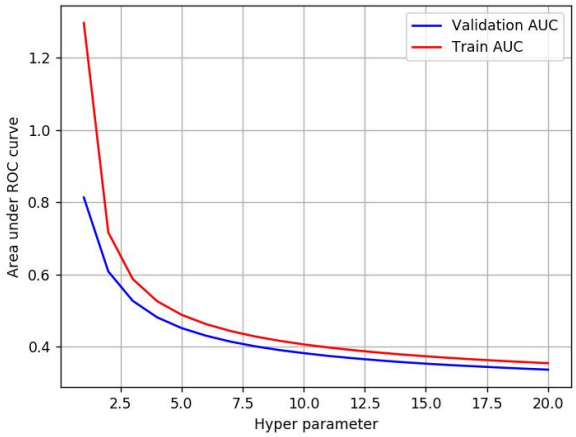
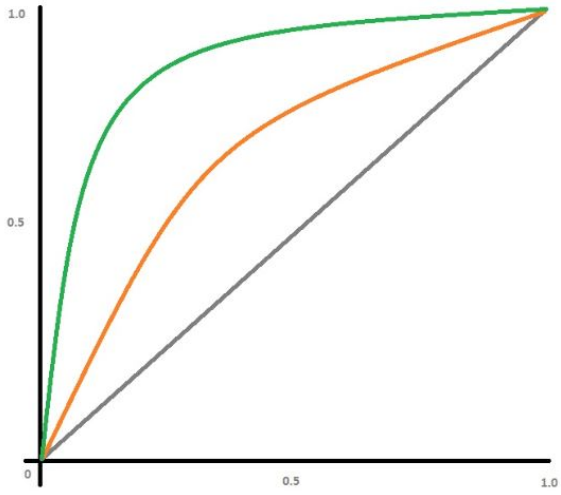
# Assignment 6: Apply NB

1. **Apply Multinomial NB on these feature sets**
    - Set 1: categorical, numerical features + preprocessed_eassay (BOW)
    - Set 2: categorical, numerical features + preprocessed_eassay (TFIDF)
2. **The hyper paramter tuning(find best alpha:smoothing parameter)**
    - Find the best hyper parameter which will give the maximum AUC (https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/receiver-operating-characteristic-curve-roc-curve-and-auc-1/) value
    - find the best hyper paramter using k-fold cross validation(use GridsearchCV or RandomsearchCV)/simple cross validation data (write for loop to iterate over hyper parameter values)
    -
3. **Representation of results**
    - You need to plot the performance of model both on train data and cross validation data for each hyper parameter, like shown in the figure




- Once after you found the best hyper parameter, you need to train your model with it, and find the AUC on test data and plot the ROC curve on both train and test.




- Along with plotting ROC curve, you need to print the confusion matrix (https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/confusion-matrix-tpr-fpr-fnr-tnr-1/) with predicted and original labels of test data points

| | Predicted: NO | Predicted: YES |
|---|---|---|
| Actual: NO | TN = ?? | FP = ?? |
| Actual: YES | FN = ?? | TP = ?? |

4. fine the top 20 features from either from feature Set 1 or feature Set 2 using absolute values of `feature_log_prob_ ` parameter of `MultinomialNB` (https://scikit-learn.org/stable/modules/generated/sklearn.naive_bayes.MultinomialNB.html) and print their corresponding feature names
5. You need to summarize the results at the end of the notebook, summarize it in the table format

| Vectorizer | Model | Hyper parameter | AUC |
|---|---|---|---|
| BOW | Brute | 7 | 0.78 |
| TFIDF | Brute | 12 | 0.79 |

# 2. Naive Bayes

## 1.1 Loading Data

In [1]:

```
%matplotlib inline
import warnings
warnings.filterwarnings("ignore")

import numpy as np
import nltk
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.feature_extraction.text import CountVectorizer
from sklearn.metrics import confusion_matrix
from sklearn import metrics
from sklearn.metrics import roc_curve, auc

import re
import pickle
from tqdm import tqdm
import os
from collections import Counter

import pandas as pd
data = pd.read_csv('preprocessed_data.csv')
y = data['project_is_approved'].values
X = data.drop(['project_is_approved'], axis=1)
X.head(2)
```

Out[1]:

| | school_state | teacher_prefix | project_grade_category | teacher_number_of_previously_posted_ |
|---|---|---|---|---|
| **0** | ca | mrs | grades_prek_2 | |
| **1** | ut | ms | grades_3_5 | |

# 1.2 Splitting data into Train and cross validation(or test): Stratified Sampling

In [2]:

```
# train test CV split
from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.33, stratify=y)
X_train, X_cv, y_train, y_cv = train_test_split(X_train, y_train, test_size=0.33, strat
ify=y_train)

print(X_train.shape, y_train.shape)
print(X_cv.shape, y_cv.shape)
print(X_test.shape, y_test.shape)
```

```
(49041, 8) (49041,)
(24155, 8) (24155,)
(36052, 8) (36052,)
```

# 1.3 Make Data Model Ready: encoding eassay, and project_title

## Feature set 1 BOW

In [3]:

```
#BOW of essay
preprocessed_essays = data['essay'].values
```

In [4]:

```
# We are considering only the words which appeared in at least 10 documents(rows or pro
jects).
vectorizer = CountVectorizer(min_df=10)
text_bow = vectorizer.fit_transform(preprocessed_essays)
print("Shape of matrix after one hot encodig ",text_bow.shape)

# we use the fitted CountVectorizer to convert the text to vector
X_train_essay_bow = vectorizer.transform(X_train['essay'].values)
X_cv_essay_bow = vectorizer.transform(X_cv['essay'].values)
X_test_essay_bow = vectorizer.transform(X_test['essay'].values)

#Feture_name_BOW
feature_names_bow=[]
feature_names_bow.extend(vectorizer.get_feature_names())
```

```
Shape of matrix after one hot encodig  (109248, 16623)
```

In [5]:

```
#TFIDF of essay
from sklearn.feature_extraction.text import TfidfVectorizer
vectorizer = TfidfVectorizer(min_df=10)
text_tfidf = vectorizer.fit_transform(preprocessed_essays)
print("Shape of matrix after one hot encodig ",text_tfidf.shape)

X_train_essay_tfidf = vectorizer.transform(X_train['essay'].values)
X_cv_essay_tfidf = vectorizer.transform(X_cv['essay'].values)
X_test_essay_tfidf = vectorizer.transform(X_test['essay'].values)

#Feture_name_tfidf
feature_names_tfidf=[]
feature_names_tfidf.extend(vectorizer.get_feature_names())
```

```
Shape of matrix after one hot encodig  (109248, 16623)
```

# 1.4 Make Data Model Ready: encoding numerical, categorical features

In [6]:

```
#school state
vectorizer = CountVectorizer()
vectorizer.fit(X_train['school_state'].values) # fit has to happen only on train data

# we use the fitted CountVectorizer to convert the text to vector
X_train_state_ohe = vectorizer.transform(X_train['school_state'].values)
X_cv_state_ohe = vectorizer.transform(X_cv['school_state'].values)
X_test_state_ohe = vectorizer.transform(X_test['school_state'].values)

feature_names_bow.extend(vectorizer.get_feature_names())
feature_names_tfidf.extend(vectorizer.get_feature_names())

print("After vectorizations")
print(X_train_state_ohe.shape, y_train.shape)
print(X_cv_state_ohe.shape, y_cv.shape)
print(X_test_state_ohe.shape, y_test.shape)
print(vectorizer.get_feature_names())
print("="*100)

#teacher_prefix
vectorizer = CountVectorizer()
vectorizer.fit(X_train['teacher_prefix'].values) # fit has to happen only on train data

# we use the fitted CountVectorizer to convert the text to vector
X_train_teacher_ohe = vectorizer.transform(X_train['teacher_prefix'].values)
X_cv_teacher_ohe = vectorizer.transform(X_cv['teacher_prefix'].values)
X_test_teacher_ohe = vectorizer.transform(X_test['teacher_prefix'].values)

feature_names_bow.extend(vectorizer.get_feature_names())
feature_names_tfidf.extend(vectorizer.get_feature_names())

print("After vectorizations")
print(X_train_teacher_ohe.shape, y_train.shape)
print(X_cv_teacher_ohe.shape, y_cv.shape)
print(X_test_teacher_ohe.shape, y_test.shape)
print(vectorizer.get_feature_names())
print("="*100)

#project grade
vectorizer = CountVectorizer()
vectorizer.fit(X_train['project_grade_category'].values) # fit has to happen only on tr
ain data

# we use the fitted CountVectorizer to convert the text to vector
X_train_grade_ohe = vectorizer.transform(X_train['project_grade_category'].values)
X_cv_grade_ohe = vectorizer.transform(X_cv['project_grade_category'].values)
X_test_grade_ohe = vectorizer.transform(X_test['project_grade_category'].values)

feature_names_bow.extend(vectorizer.get_feature_names())
feature_names_tfidf.extend(vectorizer.get_feature_names())

print("After vectorizations")
print(X_train_grade_ohe.shape, y_train.shape)
print(X_cv_grade_ohe.shape, y_cv.shape)
print(X_test_grade_ohe.shape, y_test.shape)
print(vectorizer.get_feature_names())
print("="*100)

#Encoding numerical feature price
```

```
from sklearn.preprocessing import Normalizer
normalizer = Normalizer()

normalizer.fit(X_train['price'].values.reshape(1,-1))

X_train_price_norm1 = normalizer.transform(X_train['price'].values.reshape(1,-1))
X_cv_price_norm1 = normalizer.transform(X_cv['price'].values.reshape(1,-1))
X_test_price_norm1 = normalizer.transform(X_test['price'].values.reshape(1,-1))

X_train_price_norm=X_train_price_norm1.reshape(-1,1)
X_cv_price_norm=X_cv_price_norm1.reshape(-1,1)
X_test_price_norm=X_test_price_norm1.reshape(-1,1)

feature_names_bow.extend(['Price'])
feature_names_tfidf.extend(['Price'])

print("After vectorizations")
print(X_train_price_norm.shape, y_train.shape)
print(X_cv_price_norm.shape, y_cv.shape)
print(X_test_price_norm.shape, y_test.shape)
print("="*100)


#clean_categories
vectorizer = CountVectorizer()
vectorizer.fit(X_train['clean_categories'].values) # fit has to happen only on train da
ta

# we use the fitted CountVectorizer to convert the text to vector
X_train_clean_categories_ohe = vectorizer.transform(X_train['clean_categories'].values)
X_cv_clean_categories_ohe = vectorizer.transform(X_cv['clean_categories'].values)
X_test_clean_categories_ohe = vectorizer.transform(X_test['clean_categories'].values)


feature_names_bow.extend(vectorizer.get_feature_names())
feature_names_tfidf.extend(vectorizer.get_feature_names())

print("After vectorizations")
print(X_train_clean_categories_ohe.shape, y_train.shape)
print(X_cv_clean_categories_ohe.shape, y_cv.shape)
print(X_test_clean_categories_ohe.shape, y_test.shape)
print(vectorizer.get_feature_names())
print("="*100)

#clean_subcategories
vectorizer = CountVectorizer()
vectorizer.fit(X_train['clean_subcategories'].values) # fit has to happen only on train
data

# we use the fitted CountVectorizer to convert the text to vector
X_train_clean_subcategories_ohe = vectorizer.transform(X_train['clean_subcategories'].v
alues)
X_cv_clean_subcategories_ohe = vectorizer.transform(X_cv['clean_subcategories'].values)
X_test_clean_subcategories_ohe = vectorizer.transform(X_test['clean_subcategories'].val
ues)

feature_names_bow.extend(vectorizer.get_feature_names())
feature_names_tfidf.extend(vectorizer.get_feature_names())

print("After vectorizations")
print(X_train_clean_subcategories_ohe.shape, y_train.shape)
```

```
print(X_cv_clean_subcategories_ohe.shape, y_cv.shape)
print(X_test_clean_subcategories_ohe.shape, y_test.shape)
print(vectorizer.get_feature_names())
print("="*100)

#teacher_number_of_previously_posted_projects
from sklearn.preprocessing import Normalizer
normalizer = Normalizer()
normalizer.fit(X_train['teacher_number_of_previously_posted_projects'].values.reshape(1
,-1))

X_train_previous_proj_norm1 = normalizer.transform(X_train['teacher_number_of_previousl
y_posted_projects'].values.reshape(1,-1))
X_cv_previous_proj_norm1 = normalizer.transform(X_cv['teacher_number_of_previously_post
ed_projects'].values.reshape(1,-1))
X_test_previous_proj_norm1 = normalizer.transform(X_test['teacher_number_of_previously_
posted_projects'].values.reshape(1,-1))

X_train_previous_proj_norm=X_train_previous_proj_norm1.reshape(-1,1)
X_cv_previous_proj_norm=X_cv_previous_proj_norm1.reshape(-1,1)
X_test_previous_proj_norm=X_test_previous_proj_norm1.reshape(-1,1)

feature_names_bow.extend(['teacher_number_of_previously_posted_projects'])
feature_names_tfidf.extend(['teacher_number_of_previously_posted_projects'])

print("After vectorizations")
print(X_train_previous_proj_norm.shape, y_train.shape)
print(X_cv_previous_proj_norm.shape, y_cv.shape)
print(X_test_previous_proj_norm.shape, y_test.shape)
print("="*100)

print(len(feature_names_bow))
print(len(feature_names_tfidf))
```

```
After vectorizations
(49041, 51) (49041,)
(24155, 51) (24155,)
(36052, 51) (36052,)
['ak', 'al', 'ar', 'az', 'ca', 'co', 'ct', 'dc', 'de', 'fl', 'ga', 'hi',
'ia', 'id', 'il', 'in', 'ks', 'ky', 'la', 'ma', 'md', 'me', 'mi', 'mn', 'm
o', 'ms', 'mt', 'nc', 'nd', 'ne', 'nh', 'nj', 'nm', 'nv', 'ny', 'oh', 'o
k', 'or', 'pa', 'ri', 'sc', 'sd', 'tn', 'tx', 'ut', 'va', 'vt', 'wa', 'w
i', 'wv', 'wy']
==========================================================================
==========================
After vectorizations
(49041, 5) (49041,)
(24155, 5) (24155,)
(36052, 5) (36052,)
['dr', 'mr', 'mrs', 'ms', 'teacher']
==========================================================================
==========================
After vectorizations
(49041, 4) (49041,)
(24155, 4) (24155,)
(36052, 4) (36052,)
['grades_3_5', 'grades_6_8', 'grades_9_12', 'grades_prek_2']
==========================================================================
==========================
After vectorizations
(49041, 1) (49041,)
(24155, 1) (24155,)
(36052, 1) (36052,)
==========================================================================
==========================
After vectorizations
(49041, 9) (49041,)
(24155, 9) (24155,)
(36052, 9) (36052,)
['appliedlearning', 'care_hunger', 'health_sports', 'history_civics', 'lit
eracy_language', 'math_science', 'music_arts', 'specialneeds', 'warmth']
==========================================================================
==========================
After vectorizations
(49041, 30) (49041,)
(24155, 30) (24155,)
(36052, 30) (36052,)
['appliedsciences', 'care_hunger', 'charactereducation', 'civics_governmen
t', 'college_careerprep', 'communityservice', 'earlydevelopment', 'economi
cs', 'environmentalscience', 'esl', 'extracurricular', 'financialliterac
y', 'foreignlanguages', 'gym_fitness', 'health_lifescience', 'health_welln
ess', 'history_geography', 'literacy', 'literature_writing', 'mathematic
s', 'music', 'nutritioneducation', 'other', 'parentinvolvement', 'performi
ngarts', 'socialsciences', 'specialneeds', 'teamsports', 'visualarts', 'wa
rmth']
==========================================================================
==========================
After vectorizations
(49041, 1) (49041,)
(24155, 1) (24155,)
(36052, 1) (36052,)
==========================================================================
==========================
16724
16724
```

## Feature Set 1

In [7]:

```
# Ref https://stackoverflow.com/a/19710648/4084039
#Stack the vectorizwe feture set 1 BOW

from scipy.sparse import hstack
X_tr = hstack((X_train_essay_bow, X_train_state_ohe, X_train_teacher_ohe, X_train_grade
_ohe, X_train_price_norm,X_train_clean_categories_ohe,X_train_clean_subcategories_ohe,X
_train_previous_proj_norm)).tocsr()
X_cr = hstack((X_cv_essay_bow, X_cv_state_ohe, X_cv_teacher_ohe, X_cv_grade_ohe, X_cv_p
rice_norm,X_cv_clean_categories_ohe,X_cv_clean_subcategories_ohe,X_cv_previous_proj_nor
m)).tocsr()
X_te = hstack((X_test_essay_bow, X_test_state_ohe, X_test_teacher_ohe, X_test_grade_ohe
, X_test_price_norm,X_test_clean_categories_ohe,X_test_clean_subcategories_ohe,X_test_p
revious_proj_norm)).tocsr()

print("Final Data matrix")
print(X_tr.shape, y_train.shape)
print(X_cr.shape, y_cv.shape)
print(X_te.shape, y_test.shape)
print("="*100)

#feature_lst will contin the feture names and correponding column id
feature_lst=[]
a=X_train_essay_bow.shape[1]
b=X_train_state_ohe.shape[1]
c=X_train_teacher_ohe.shape[1]
d=X_train_grade_ohe.shape[1]
e=X_train_price_norm.shape[1]
f=X_train_clean_categories_ohe.shape[1]
g=X_train_clean_subcategories_ohe.shape[1]
h=X_train_previous_proj_norm.shape[1]

for i in range(int(a)):
    feature_lst.append('essay')

for i in range(int(b)):
    feature_lst.append('school_state')

for i in range(int(c)):
    feature_lst.append('teacher_prefix')

for i in range(int(d)):
    feature_lst.append('project_grade_category')

for i in range(int(e)):
    feature_lst.append('price')

for i in range(int(f)):
    feature_lst.append('clean_categories')

for i in range(int(g)):
    feature_lst.append('clean_subcategories')

for i in range(int(h)):
    feature_lst.append('teacher_number_of_previously_posted_projects')
```

```
Final Data matrix
(49041, 16724) (49041,)
(24155, 16724) (24155,)
(36052, 16724) (36052,)
==========================================================================
==========================
```

## Feature set 2 TFIDF

In [8]:

```
# Ref https://stackoverflow.com/a/19710648/4084039
#Stack the vectorize feture set 2 TFIDF

from scipy.sparse import hstack
X_tr_tfidf = hstack((X_train_essay_tfidf, X_train_state_ohe, X_train_teacher_ohe, X_tra
in_grade_ohe, X_train_price_norm,X_train_clean_categories_ohe,X_train_clean_subcategori
es_ohe,X_train_previous_proj_norm)).tocsr()
X_cr_tfidf = hstack((X_cv_essay_tfidf, X_cv_state_ohe, X_cv_teacher_ohe, X_cv_grade_ohe
, X_cv_price_norm,X_cv_clean_categories_ohe,X_cv_clean_subcategories_ohe,X_cv_previous_
proj_norm)).tocsr()
X_te_tfidf = hstack((X_test_essay_tfidf, X_test_state_ohe, X_test_teacher_ohe, X_test_g
rade_ohe, X_test_price_norm,X_test_clean_categories_ohe,X_test_clean_subcategories_ohe,
X_test_previous_proj_norm)).tocsr()

print("Final Data matrix")
print(X_tr_tfidf.shape, y_train.shape)
print(X_cr_tfidf.shape, y_cv.shape)
print(X_te_tfidf.shape, y_test.shape)
print("="*100)

#feature_lst will contin the feture names and correponding column id
feature_lst_tfidf=[]

a=X_train_essay_tfidf.shape[1]
b=X_train_state_ohe.shape[1]
c=X_train_teacher_ohe.shape[1]
d=X_train_grade_ohe.shape[1]
e=X_train_price_norm.shape[1]
f=X_train_clean_categories_ohe.shape[1]
g=X_train_clean_subcategories_ohe.shape[1]
h=X_train_previous_proj_norm.shape[1]

for i in range(int(a)):
    feature_lst_tfidf.append('essay')

for i in range(int(b)):
    feature_lst_tfidf.append('school_state')

for i in range(int(c)):
    feature_lst_tfidf.append('teacher_prefix')

for i in range(int(d)):
    feature_lst_tfidf.append('project_grade_category')

for i in range(int(e)):
    feature_lst_tfidf.append('price')

for i in range(int(f)):
    feature_lst_tfidf.append('clean_categories')

for i in range(int(g)):
    feature_lst_tfidf.append('clean_subcategories')

for i in range(int(h)):
    feature_lst_tfidf.append('teacher_number_of_previously_posted_projects')
```

```
Final Data matrix
(49041, 16724) (49041,)
(24155, 16724) (24155,)
(36052, 16724) (36052,)
==========================================================================
==========================
```

# 1.5 Appling NB on different kind of featurization as mentioned in the instructions

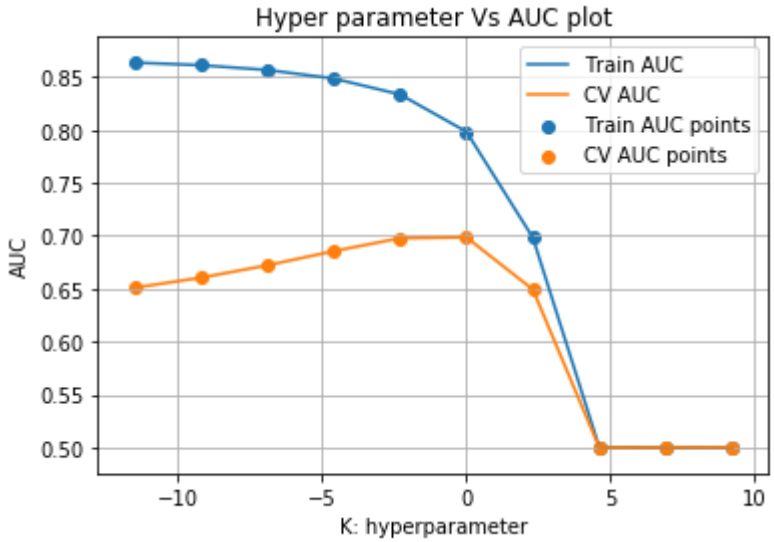
Apply NB on different kind of featurization as mentioned in the instructions
For Every model that you work on make sure you do the step 2 and step 3 of instrucations

## Feature set 1 BOW

In [9]:

```
#Ref https://scikit-learn.org/stable/modules/generated/sklearn.model_selection.GridSearchCV.html
from sklearn.model_selection import GridSearchCV
from scipy.stats import randint as sp_randint
from sklearn.model_selection import RandomizedSearchCV
from sklearn.naive_bayes import MultinomialNB

nb=MultinomialNB(fit_prior = True, class_prior = [.5, .5])
parameters = {'alpha':[0.00001,0.0001,0.001,0.01,0.1,1,10,100,1000,10000]}
#alpha=[0.00001,0.0001,0.001,0.01,0.1,1,10,100,1000,10000]
clf = RandomizedSearchCV(nb, parameters , cv=10, scoring='roc_auc',return_train_score=True)
clf.fit(X_tr, y_train)
results = pd.DataFrame.from_dict(clf.cv_results_)

results = results.sort_values(['param_alpha'])

train_auc= results['mean_train_score']
train_auc_std= results['std_train_score']
cv_auc = results['mean_test_score']
cv_auc_std= results['std_test_score']
K =  results['param_alpha']
k1=[]
for ele in K:
    k1.append(np.log(ele))
print(K)
print(k1)

plt.plot(k1, train_auc, label='Train AUC')
# Ref https://stackoverflow.com/a/48803361/4084039
plt.plot(k1, cv_auc, label='CV AUC')
plt.scatter(k1, train_auc, label='Train AUC points')
plt.scatter(k1, cv_auc, label='CV AUC points')

plt.legend()
plt.xlabel("K: hyperparameter")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()

results.head()
```

```
0     1e-05
1    0.0001
2     0.001
3      0.01
4       0.1
5         1
6        10
7       100
8      1000
9     10000
Name: param_alpha, dtype: object
[-11.512925464970229, -9.210340371976182, -6.907755278982137, -4.605170185
988091, -2.3025850929940455, 0.0, 2.302585092994046, 4.605170185988092, 6.
907755278982137, 9.210340371976184]
```




Out[9]:

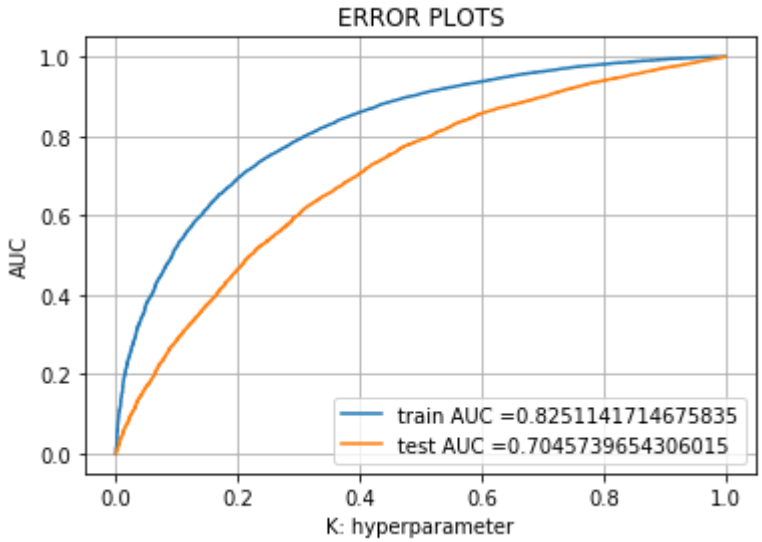
| | mean_fit_time | std_fit_time | mean_score_time | std_score_time | param_alpha | params | split |
|---|---|---|---|---|---|---|---|
| **0** | 0.196480 | 0.036180 | 0.013491 | 0.003979 | 1e-05 | {'alpha': 1e-05} | |
| **1** | 0.183887 | 0.013205 | 0.011392 | 0.001685 | 0.0001 | {'alpha': 0.0001} | |
| **2** | 0.180990 | 0.011088 | 0.010992 | 0.001342 | 0.001 | {'alpha': 0.001} | |
| **3** | 0.185487 | 0.020700 | 0.012592 | 0.003468 | 0.01 | {'alpha': 0.01} | |
| **4** | 0.189085 | 0.027950 | 0.011492 | 0.002905 | 0.1 | {'alpha': 0.1} | |

5 rows × 31 columns

In [10]:

```
#best alpha =0.1
best_k = 0.1
from sklearn.metrics import roc_curve, auc

def batch_predict(clf, data):
    y_data_pred = []
    tr_loop = data.shape[0] - data.shape[0]%1000
    for i in range(0, tr_loop, 1000):
        y_data_pred.extend(clf.predict_proba(data[i:i+1000])[:,1])
    if data.shape[0]%1000 !=0:
        y_data_pred.extend(clf.predict_proba(data[tr_loop:])[:,1])
    return y_data_pred


nb = MultinomialNB(alpha=best_k,fit_prior = True, class_prior = [.5, .5])
nb.fit(X_tr, y_train)

max_ind_neg=np.argsort((nb.feature_log_prob_)[0][::-1][0:20])
top_neg=np.take(feature_names_bow,max_ind_neg)
print(" class 0: Important Feature column name ")
print(top_neg)

max_ind_pos=np.argsort((nb.feature_log_prob_)[1][::-1][0:20])
top_pos=np.take(feature_names_bow,max_ind_pos)
print(" class 1: Important Feature column name ")
print(top_pos)

y_train_pred = batch_predict(nb, X_tr)
y_test_pred = batch_predict(nb, X_te)

train_fpr, train_tpr, tr_thresholds = roc_curve(y_train, y_train_pred)
test_fpr, test_tpr, te_thresholds = roc_curve(y_test, y_test_pred)

plt.plot(train_fpr, train_tpr, label="train AUC ="+str(auc(train_fpr, train_tpr)))
plt.plot(test_fpr, test_tpr, label="test AUC ="+str(auc(test_fpr, test_tpr)))
plt.legend()
plt.xlabel("K: hyperparameter")
plt.ylabel("AUC")
plt.title("ERROR PLOTS")
plt.grid()
plt.show()
```

```
 class 0: Important Feature column name
['00' '11' '1000' '000' '10th' '100' '100th' '10' '101' '100s' '00pm'
 '105' '108' '10s' '00am' '107' '03' '103' '104' '102']
 class 1: Important Feature column name
['00' '11' '1000' '10th' '100th' '000' '100' '10' '00pm' '100s' '101'
 '105' '108' '10s' '00am' '107' '03' '103' '102' '104']
```




In [11]:

```
# we will pick a threshold that will give the least fpr
def find_best_threshold(threshould, fpr, tpr):
    t = threshould[np.argmax(tpr*(1-fpr))]
    # (tpr*(1-fpr)) will be maximum if your fpr is very low and tpr is very high
    print("the maximum value of tpr*(1-fpr)", max(tpr*(1-fpr)), "for threshold", np.rou
nd(t,3))
    return t

def predict_with_best_t(proba, threshould):
    predictions = []
    for i in proba:
        if i>=threshould:
            predictions.append(1)
        else:
            predictions.append(0)
    return predictions
```

In [12]:

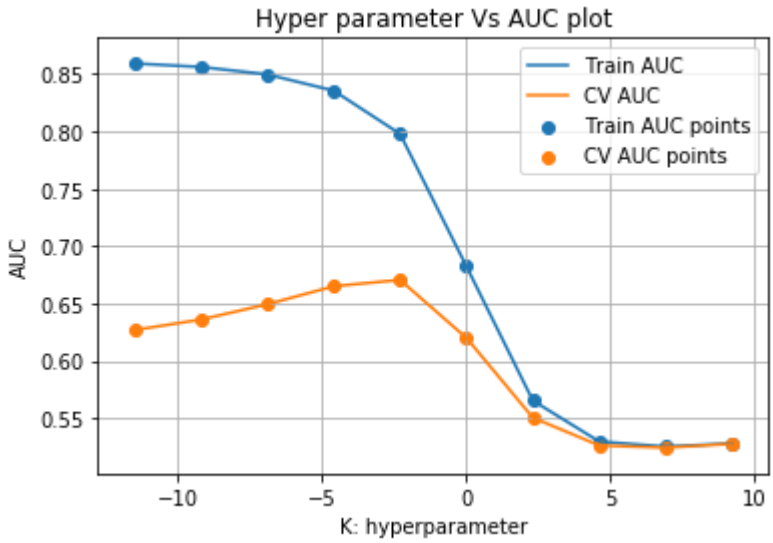
```
print("="*100)
from sklearn.metrics import confusion_matrix
best_t = find_best_threshold(tr_thresholds, train_fpr, train_tpr)
print("Train confusion matrix")
print(confusion_matrix(y_train, predict_with_best_t(y_train_pred, best_t)))
print("Test confusion matrix")
print(confusion_matrix(y_test, predict_with_best_t(y_test_pred, best_t)))
```

```
====================================================================================================
==========================
the maximum value of tpr*(1-fpr) 0.5621621950459075 for threshold 0.522
Train confusion matrix
[[ 5592  1834]
 [10548 31067]]
Test confusion matrix
[[ 3213  2246]
 [ 8594 21999]]
```

## Feature set 2 TFIDF

In [13]:

```
#Ref https://scikit-learn.org/stable/modules/generated/sklearn.model_selection.GridSearchCV.html
from sklearn.model_selection import GridSearchCV
from scipy.stats import randint as sp_randint
from sklearn.model_selection import RandomizedSearchCV
from sklearn.naive_bayes import MultinomialNB

nb=MultinomialNB(fit_prior = True, class_prior = [.5, .5])
parameters = {'alpha':[0.00001,0.0001,0.001,0.01,0.1,1,10,100,1000,10000]}
clf = RandomizedSearchCV(nb, parameters, cv=10, scoring='roc_auc',return_train_score=True)
clf.fit(X_tr_tfidf, y_train)
results = pd.DataFrame.from_dict(clf.cv_results_)
results = results.sort_values(['param_alpha'])

train_auc_tfidf= results['mean_train_score']
train_auc_std_tfidf= results['std_train_score']
cv_auc_tfidf = results['mean_test_score']
cv_auc_std_tfidf= results['std_test_score']
K =  results['param_alpha']
k1=[]
for ele in K:
    k1.append(np.log(ele))

plt.plot(k1, train_auc_tfidf, label='Train AUC')
# Ref https://stackoverflow.com/a/48803361/4084039
plt.plot(k1, cv_auc_tfidf, label='CV AUC')
plt.scatter(k1, train_auc_tfidf, label='Train AUC points')
plt.scatter(k1, cv_auc_tfidf, label='CV AUC points')

plt.legend()
plt.xlabel("K: hyperparameter")
plt.ylabel("AUC")
plt.title("Hyper parameter Vs AUC plot")
plt.grid()
plt.show()

results.head()
```




Out[13]:

| | mean_fit_time | std_fit_time | mean_score_time | std_score_time | param_alpha | params | split |
|---|---|---|---|---|---|---|---|
| **0** | 0.200577 | 0.026954 | 0.012893 | 0.001972 | 1e-05 | {'alpha': 1e-05} | |
| **1** | 0.200877 | 0.014646 | 0.013792 | 0.002441 | 0.0001 | {'alpha': 0.0001} | |
| **2** | 0.209671 | 0.027382 | 0.013093 | 0.003643 | 0.001 | {'alpha': 0.001} | |
| **3** | 0.185387 | 0.013506 | 0.011793 | 0.001400 | 0.01 | {'alpha': 0.01} | |
| **4** | 0.191083 | 0.019756 | 0.011793 | 0.002134 | 0.1 | {'alpha': 0.1} | |

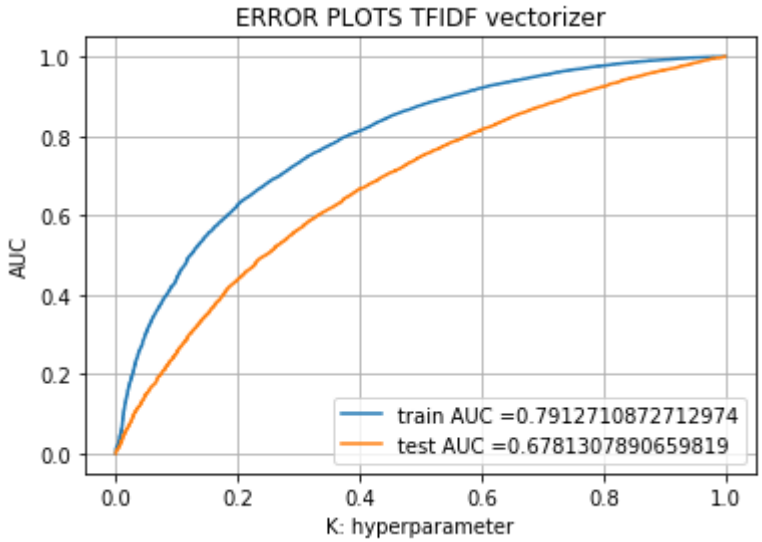
5 rows × 31 columns

## Feature set 2 TFIDF

In [14]:

```
#best alpha =0.1
best_k_tfidf = 0.1
from sklearn.metrics import roc_curve, auc

def batch_predict(clf, data):
    y_data_pred = []
    tr_loop = data.shape[0] - data.shape[0]%1000
    for i in range(0, tr_loop, 1000):
        y_data_pred.extend(clf.predict_proba(data[i:i+1000])[:,1])
    if data.shape[0]%1000 !=0:
        y_data_pred.extend(clf.predict_proba(data[tr_loop:])[:,1])
    return y_data_pred


nb = MultinomialNB(alpha=best_k_tfidf,fit_prior = True, class_prior = [.5, .5])
nb.fit(X_tr_tfidf, y_train)

max_ind_neg_tfidf=np.argsort((nb.feature_log_prob_)[0][::-1][0:20])
top_neg_tfidf=np.take(feature_names_tfidf,max_ind_neg_tfidf)
print(" class 0: Important Feature column name ")
print(top_neg_tfidf)

max_ind_pos_tfidf=np.argsort((nb.feature_log_prob_)[1][::-1][0:20])
top_pos_tfidf=np.take(feature_names_tfidf,max_ind_pos_tfidf)
print(" class 1: Important Feature column name ")
print(top_pos_tfidf)

y_train_pred = batch_predict(nb, X_tr_tfidf)
y_test_pred = batch_predict(nb, X_te_tfidf)

train_fpr_tfidf, train_tpr_tfidf, tr_thresholds_tfidf = roc_curve(y_train, y_train_pred
)
test_fpr_tfidf, test_tpr_tfidf, te_thresholds_tfidf = roc_curve(y_test, y_test_pred)

plt.plot(train_fpr_tfidf, train_tpr_tfidf, label="train AUC ="+str(auc(train_fpr_tfidf,
train_tpr_tfidf)))
plt.plot(test_fpr_tfidf, test_tpr_tfidf, label="test AUC ="+str(auc(test_fpr_tfidf, tes
t_tpr_tfidf)))
plt.legend()
plt.xlabel("K: hyperparameter")
plt.ylabel("AUC")
plt.title("ERROR PLOTS TFIDF vectorizer")
plt.grid()
plt.show()
```

```
 class 0: Important Feature column name
['00' '11' '1000' '000' '10th' '100' '100th' '10' '101' '100s' '00pm'
 '105' '108' '10s' '00am' '107' '03' '103' '104' '102']
 class 1: Important Feature column name
['00' '11' '1000' '10th' '100th' '000' '100' '10' '00pm' '100s' '101'
 '105' '108' '10s' '00am' '107' '03' '103' '102' '104']
```




### Feature set 2 TFIDF

In [15]:

```
print("="*100)
from sklearn.metrics import confusion_matrix
best_t_tfidf = find_best_threshold(tr_thresholds_tfidf, train_fpr_tfidf, train_tpr_tfid
f)
print("Train confusion matrix TFIDF vectorizer")
print(confusion_matrix(y_train, predict_with_best_t(y_train_pred, best_t_tfidf)))
print("Test confusion matrix TFIDF Vextorizer")
print(confusion_matrix(y_test, predict_with_best_t(y_test_pred, best_t_tfidf)))
```

```
====================================================================================
==========================
the maximum value of tpr*(1-fpr) 0.5136970489784926 for threshold 0.5
Train confusion matrix TFIDF vectorizer
[[ 5289  2137]
 [11600 30015]]
Test confusion matrix TFIDF Vextorizer
[[ 3119  2340]
 [ 9544 21049]]
```

# 3. Summary

as mentioned in the step 5 of instructions

In [16]:

```
#Ref http://zetcode.com/python/prettytable/
from prettytable import PrettyTable

x = PrettyTable()
x.field_names = ["Vectorizer", "Model", "Hyper parameter","AUC"]

for i in range(1):
    x.add_row(["BOW","Brute force", best_k, auc(test_fpr, test_tpr)])

for i in range(1):
    x.add_row(["TFIDF","Brute force", best_k_tfidf, auc(test_fpr_tfidf, test_tpr_tfidf
)])
print(x)
```

```
+------------+-------------+-----------------+--------------------+
| Vectorizer |    Model    | Hyper parameter |        AUC         |
+------------+-------------+-----------------+--------------------+
|    BOW     | Brute force |       0.1       | 0.7045739654306015 |
|   TFIDF    | Brute force |       0.1       | 0.6781307890659819 |
+------------+-------------+-----------------+--------------------+
```

In [ ]:

In [ ]: