Assignment 2

split data

In [30]:
```
!pip install mlxtend



import math
import pandas as pd
import numpy as np
from operator import itemgetter


import matplotlib.pyplot as plt
import seaborn as sns


from sklearn.model_selection import train_test_split
import sklearn.metrics as metrics
from sklearn.linear_model import LogisticRegression

from sklearn.linear_model import LinearRegression

from sklearn import tree
from sklearn.tree import _tree

from sklearn.ensemble import RandomForestRegressor
from sklearn.ensemble import RandomForestClassifier

from sklearn.ensemble import GradientBoostingRegressor
from sklearn.ensemble import GradientBoostingClassifier

from sklearn.metrics import classification_report, confusion_matrix

from mlxtend.feature_selection import SequentialFeatureSelector as SFS
from mlxtend.plotting import plot_sequential_feature_selection as plot_sfs
```

```
Requirement already satisfied: mlxtend in c:\anaconda\lib\site-packages (0.23.1)
Requirement already satisfied: scipy>=1.2.1 in c:\anaconda\lib\site-packages (from mlxtend) (1.11.4)
Requirement already satisfied: numpy>=1.16.2 in c:\anaconda\lib\site-packages (from mlxtend) (1.26.3)
Requirement already satisfied: pandas>=0.24.2 in c:\anaconda\lib\site-packages (from mlxtend) (2.1.1)
Requirement already satisfied: scikit-learn>=1.0.2 in c:\anaconda\lib\site-packages (from mlxtend) (1.2.2)
Requirement already satisfied: matplotlib>=3.0.0 in c:\anaconda\lib\site-packages (from mlxtend) (3.8.0)
Requirement already satisfied: joblib>=0.13.2 in c:\anaconda\lib\site-packages (from mlxtend) (1.2.0)
Requirement already satisfied: contourpy>=1.0.1 in c:\anaconda\lib\site-packages (from matplotlib>=3.0.0->mlxtend) (1.2.0)
Requirement already satisfied: cycler>=0.10 in c:\anaconda\lib\site-packages (from matplotlib>=3.0.0->mlxtend) (0.11.0)
Requirement already satisfied: fonttools>=4.22.0 in c:\anaconda\lib\site-packages (from matplotlib>=3.0.0->mlxtend) (4.25.0)
Requirement already satisfied: kiwisolver>=1.0.1 in c:\anaconda\lib\site-packages (from matplotlib>=3.0.0->mlxtend) (1.4.4)
Requirement already satisfied: packaging>=20.0 in c:\anaconda\lib\site-packages (from matplotlib>=3.0.0->mlxtend) (23.1)
Requirement already satisfied: pillow>=6.2.0 in c:\anaconda\lib\site-packages (from matplotlib>=3.0.0->mlxtend) (10.2.0)
Requirement already satisfied: pyparsing>=2.3.1 in c:\anaconda\lib\site-packages (from matplotlib>=3.0.0->mlxtend) (3.0.9)
Requirement already satisfied: python-dateutil>=2.7 in c:\anaconda\lib\site-packages (from matplotlib>=3.0.0->mlxtend) (2.8.2)
Requirement already satisfied: pytz>=2020.1 in c:\anaconda\lib\site-packages (from pandas>=0.24.2->mlxtend) (2023.3.post1)
Requirement already satisfied: tzdata>=2022.1 in c:\anaconda\lib\site-packages (from pandas>=0.24.2->mlxtend) (2023.3)
Requirement already satisfied: threadpoolctl>=2.0.0 in c:\anaconda\lib\site-packages (from scikit-learn>=1.0.2->mlxtend) (2.2.0)
Requirement already satisfied: six>=1.5 in c:\anaconda\lib\site-packages (from python-dateutil>=2.7->matplotlib>=3.0.0->mlxtend) (1.16.0)
```

In [31]:
```
cleandf01 = pd.read_csv("cleandf01")
FLAG = "TARGET_BAD_FLAG"
LOSS = "TARGET_LOSS_AMT"
```

In [32]:
```
X = cleandf01.copy()
X = X.drop( FLAG, axis=1 )
X = X.drop( LOSS, axis=1 )

Y = cleandf01[ [FLAG, LOSS] ]
```

In [33]:
```
X_train, X_test, Y_train, Y_test = train_test_split(X, Y, train_size=0.8, test_size=0.2, random_state=1)
X_train, X_test, Y_train, Y_test = train_test_split(X, Y, train_size=0.8, test_size=0.2 )

print( "FLAG DATA" )
print( "TRAINING = ", X_train.shape )
print( "TEST = ", X_test.shape )
```

```
FLAG DATA
TRAINING =  (4768, 28)
TEST =  (1192, 28)
```

In [34]:
```
F = ~ Y_train[ LOSS ].isna()
W_train = X_train[F].copy()
Z_train = Y_train[F].copy()

F = ~ Y_test[ LOSS ].isna()
W_test = X_test[F].copy()
Z_test = Y_test[F].copy()

print( Z_train.describe() )
print( Z_test.describe() )
print( "\n\n")

F = Z_train[ LOSS ] > 25000
Z_train.loc[ F, LOSS ] = 25000

F = Z_test[ LOSS ] > 25000
Z_test.loc[ F, [LOSS] ] = 25000

print( Z_train.describe() )
print( Z_test.describe() )
print( "\n\n")
```

```
       TARGET_BAD_FLAG  TARGET_LOSS_AMT
count      4768.000000      4768.000000
mean          0.202601      5166.708054
std           0.401980      6321.120623
min           0.000000       320.000000
25%           0.000000      3080.000000
50%           0.000000      3080.000000
75%           0.000000      3080.000000
max           1.000000     78987.000000
       TARGET_BAD_FLAG  TARGET_LOSS_AMT
count      1192.000000      1192.000000
mean          0.187081      5041.734899
std           0.390140      6527.741578
min           0.000000       224.000000
25%           0.000000      3080.000000
50%           0.000000      3080.000000
75%           0.000000      3080.000000
max           1.000000     71653.000000



       TARGET_BAD_FLAG  TARGET_LOSS_AMT
count      4768.000000      4768.000000
mean          0.202601      4920.152685
std           0.401980      4987.965549
min           0.000000       320.000000
25%           0.000000      3080.000000
50%           0.000000      3080.000000
75%           0.000000      3080.000000
max           1.000000     25000.000000
       TARGET_BAD_FLAG  TARGET_LOSS_AMT
count      1192.000000      1192.000000
mean          0.187081      4734.830537
std           0.390140      4785.627398
min           0.000000       224.000000
25%           0.000000      3080.000000
50%           0.000000      3080.000000
75%           0.000000      3080.000000
max           1.000000     25000.000000
```

decision tree

In [35]:
```
fm01_Tree = tree.DecisionTreeClassifier( max_depth=5 )
fm01_Tree = fm01_Tree.fit( X_train, Y_train[ FLAG ] )

Y_Pred_train = fm01_Tree.predict(X_train)
Y_Pred_test = fm01_Tree.predict(X_test)

print("\n=============\n")
print("DECISION TREE\n")
print("Probability of Default")
print("Accuracy Train:",metrics.accuracy_score(Y_train[FLAG], Y_Pred_train))
print("Accuracy Test:",metrics.accuracy_score(Y_test[FLAG], Y_Pred_test))
print("\n")

probs = fm01_Tree.predict_proba(X_train)
p1 = probs[:,1]
fpr_train, tpr_train, threshold = metrics.roc_curve( Y_train[FLAG], p1)
roc_auc_train = metrics.auc(fpr_train, tpr_train)

probs = fm01_Tree.predict_proba(X_test)
p1 = probs[:,1]
fpr_test, tpr_test, threshold = metrics.roc_curve( Y_test[FLAG], p1)
roc_auc_test = metrics.auc(fpr_test, tpr_test)

fpr_tree = fpr_test
tpr_tree = tpr_test
auc_tree = roc_auc_test


plt.title('TREE ROC CURVE')
plt.plot(fpr_train, tpr_train, label = 'AUC TRAIN = %0.2f' % roc_auc_train, color="orange")
plt.plot(fpr_test, tpr_test, label = 'AUC TEST = %0.2f' % roc_auc_test, color="green")
plt.legend(loc = 'lower right')
plt.plot([0, 1], [0, 1],'r--')
plt.xlim([0, 1])
plt.ylim([0, 1])
plt.ylabel('True Positive Rate')
plt.xlabel('False Positive Rate')
plt.show()
```

```
=============

DECISION TREE

Probability of Default
Accuracy Train: 0.8955536912751678
Accuracy Test: 0.8934563758389261
```

```
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
instead.
  if not hasattr(array, "sparse") and array.dtypes.apply(is_sparse).any():
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
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  if is_sparse(pd_dtype):
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```

```
instead.
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  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
```
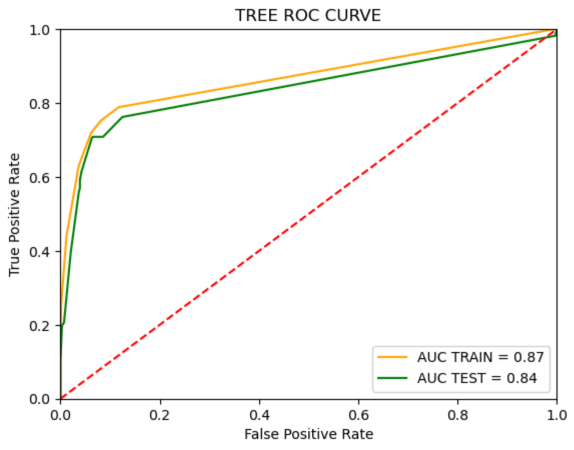
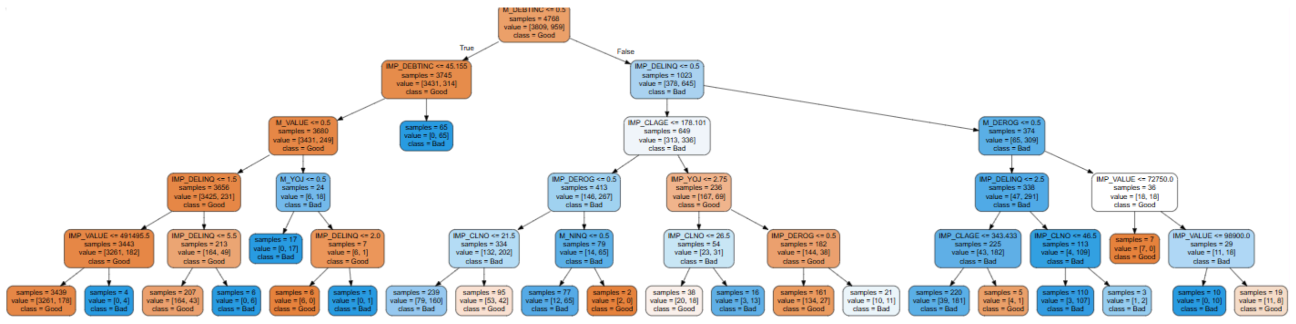



In [36]:
```python
feature_cols = list(X.columns.values )
tree.export_graphviz(fm01_Tree,out_file='tree_1.txt',filled=True, rounded=True, feature_names = feature_cols, impurity=False, class_names=["Good","Bad"]  )
```


M_DEBTINC <= 0.5 samples = 4768 value = [3809, 959] class = Good
True
False
IMP_DEBTINC <= 45.155 samples = 3745 value = [3431, 314] class = Good
IMP_DELINQ <= 0.5 samples = 1023 value = [378, 645] class = Bad
M_VALUE <= 0.5 samples = 3680 value = [3431, 249] class = Good
samples = 65 value = [0, 65] class = Bad
IMP_CLAGE <= 178.101 samples = 649 value = [313, 336] class = Bad
M_DEROG <= 0.5 samples = 374 value = [65, 309] class = Bad
IMP_DELINQ <= 1.5 samples = 3656 value = [3425, 231] class = Good
M_YOJ <= 0.5 samples = 24 value = [6, 18] class = Bad
IMP_DEROG <= 0.5 samples = 413 value = [146, 267] class = Bad
IMP_YOJ <= 2.75 samples = 236 value = [167, 69] class = Good
IMP_DELINQ <= 2.5 samples = 338 value = [47, 291] class = Bad
IMP_VALUE <= 72750.0 samples = 36 value = [18, 18] class = Good
IMP_VALUE <= 491495.5 samples = 3443 value = [3261, 182] class = Good
IMP_DELINQ <= 5.5 samples = 213 value = [164, 49] class = Good
samples = 17 value = [0, 17] class = Bad
IMP_DELINQ <= 2.0 samples = 7 value = [6, 1] class = Good
IMP_CLNO <= 21.5 samples = 334 value = [132, 202] class = Bad
M_NINQ <= 0.5 samples = 79 value = [14, 65] class = Bad
IMP_CLNO <= 26.5 samples = 54 value = [23, 31] class = Bad
IMP_DEROG <= 0.5 samples = 182 value = [144, 38] class = Good
IMP_CLAGE <= 343.433 samples = 225 value = [43, 182] class = Bad
IMP_CLNO <= 46.5 samples = 113 value = [4, 109] class = Bad
samples = 7 value = [7, 0] class = Good
IMP_VALUE <= 98900.0 samples = 29 value = [11, 18] class = Bad
samples = 3439 value = [3261, 178] class = Good
samples = 4 value = [0, 4] class = Bad
samples = 207 value = [164, 43] class = Good
samples = 6 value = [0, 6] class = Bad
samples = 6 value = [6, 0] class = Good
samples = 1 value = [0, 1] class = Bad
samples = 239 value = [79, 160] class = Bad
samples = 95 value = [53, 42] class = Good
samples = 77 value = [12, 65] class = Bad
samples = 2 value = [2, 0] class = Good
samples = 38 value = [20, 18] class = Good
samples = 16 value = [3, 13] class = Bad
samples = 161 value = [134, 27] class = Good
samples = 21 value = [10, 11] class = Bad
samples = 220 value = [39, 181] class = Bad
samples = 5 value = [4, 1] class = Good
samples = 110 value = [3, 107] class = Bad
samples = 3 value = [1, 2] class = Bad
samples = 10 value = [0, 10] class = Bad
samples = 19 value = [11, 8] class = Good

In [37]:
```python
def getTreeVars( TREE, varNames ) :
   tree_ = TREE.tree_
   varName = [ varNames[i] if i != _tree.TREE_UNDEFINED else "undefined!" for i in tree_.feature ]

   nameSet = set()
   for i in tree_.feature :
       if i != _tree.TREE_UNDEFINED :
           nameSet.add( i )
   nameList = list( nameSet )
   parameter_list = list()
   for i in nameList :
       parameter_list.append( varNames[i] )
   return parameter_list

vars_tree_flag = getTreeVars (fm01_Tree, feature_cols)

print("Important features for loan default prediction:")
for i in vars_tree_flag:
    print(i)
```

```
Important features for loan default prediction:
Unnamed: 0
OHE_REASON_DEBTCON
IMP_MORTDUE
M_VALUE
IMP_VALUE
M_YOJ
IMP_YOJ
IMP_DEROG
IMP_DELINQ
IMP_CLAGE
M_DEBTINC
IMP_DEBTINC
```

In [38]:
```python
loss_m01_Tree = tree.DecisionTreeRegressor( max_depth= 4 )
loss_m01_Tree = loss_m01_Tree.fit( W_train, Z_train[LOSS] )

Z_Pred_train = loss_m01_Tree.predict(W_train)
Z_Pred_test = loss_m01_Tree.predict(W_test)

print("\n=============\n")
print("DECISION TREE\n")
print("Predicted Accuracy of Loss Amount")
print("Accuracy Train:",metrics.accuracy_score(Y_train[LOSS], Y_Pred_train))
print("Accuracy Test:",metrics.accuracy_score(Y_test[LOSS], Y_Pred_test))
print("\n")

RMSE_TRAIN = math.sqrt( metrics.mean_squared_error(Z_train[LOSS], Z_Pred_train))
RMSE_TEST = math.sqrt( metrics.mean_squared_error(Z_test[LOSS], Z_Pred_test))

print("TREE RMSE Train:", RMSE_TRAIN )
print("TREE RMSE Test:", RMSE_TEST )

RMSE_TREE = RMSE_TEST

feature_cols = list( X.columns.values )
vars_tree_amt = getTreeVars( loss_m01_Tree, feature_cols )
tree.export_graphviz(loss_m01_Tree,out_file='tree_a.txt',filled=True, rounded=True, feature_names = feature_cols, impurity=False, precision=0  )

print("\n")
for i in vars_tree_amt :
   print(i)
```

```
=============

DECISION TREE

Predicted Accuracy of Loss Amount
Accuracy Train: 0.0
Accuracy Test: 0.0


TREE RMSE Train: 3269.8746120693045
TREE RMSE Test: 3399.6077841389447


Unnamed: 0
LOAN
IMP_YOJ
IMP_DELINQ
IMP_CLAGE
IMP_CLNO
M_DEBTINC
IMP_DEBTINC
```

```
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if not hasattr(array, "sparse") and array.dtypes.apply(is_sparse).any():
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C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
```
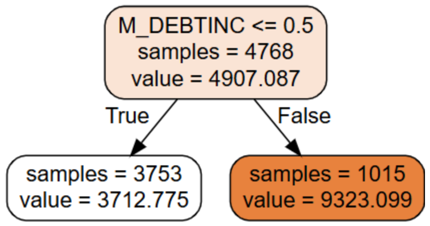

In [39]:
```
feature_cols = list(X.columns.values )
tree.export_graphviz(loss_m01_Tree,out_file='tree_2.txt',filled=True, rounded=True, feature_names = feature_cols, impurity=False, class_names=["Good","Bad"]  )
```



Random Forest

In [40]:
```
fm01_RF = RandomForestClassifier( n_estimators = 100, random_state=1 )
fm01_RF = fm01_RF.fit( X_train, Y_train[ FLAG] )
```

```
Y_Pred_train = fm01_RF.predict(X_train)
Y_Pred_test = fm01_RF.predict(X_test)


print("\n=============\n")
print("RANDOM FOREST\n")
print("Probability of default")
print("Accuracy Train:",metrics.accuracy_score(Y_train[FLAG], Y_Pred_train))
print("Accuracy Test:",metrics.accuracy_score(Y_test[FLAG], Y_Pred_test))
print("\n")
```

```
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if not hasattr(array, "sparse") and array.dtypes.apply(is_sparse).any():
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  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
```

```
=============

RANDOM FOREST

Probability of default
Accuracy Train: 1.0
Accuracy Test: 0.915268456375839
```

```
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
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  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
```

In [41]:
```
probs = fm01_RF.predict_proba(X_train)
p1 = probs[:,1]
fpr_train, tpr_train, threshold = metrics.roc_curve( Y_train[FLAG], p1)
roc_auc_train = metrics.auc(fpr_train, tpr_train)

probs = fm01_RF.predict_proba(X_test)
p1 = probs[:,1]
fpr_test, tpr_test, threshold = metrics.roc_curve( Y_test[FLAG], p1)
roc_auc_test = metrics.auc(fpr_test, tpr_test)

fpr_RF = fpr_test
tpr_RF = tpr_test
auc_RF = roc_auc_test


# %%
plt.title('RF ROC CURVE')
plt.plot(fpr_train, tpr_train, label = 'AUC TRAIN = %0.2f' % roc_auc_train, color="green")
plt.plot(fpr_test, tpr_test, label = 'AUC TEST = %0.2f' % roc_auc_test, color="purple")
plt.legend(loc = 'lower right')
plt.plot([0, 1], [0, 1],'r--')
plt.xlim([0, 1])
plt.ylim([0, 1])
plt.ylabel('True Positive Rate')
plt.xlabel('False Positive Rate')
plt.show()
```

```
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if not hasattr(array, "sparse") and array.dtypes.apply(is_sparse).any():
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  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
```

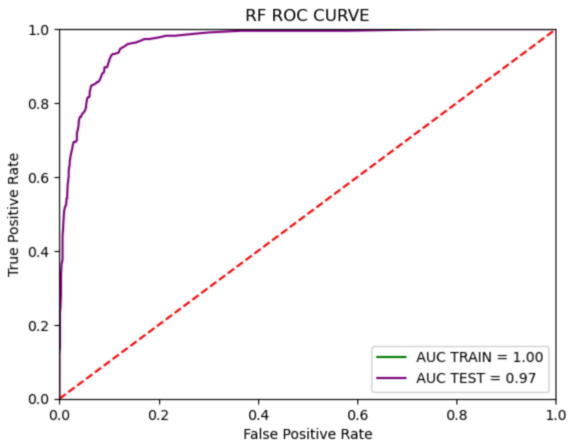

In [42]:
```
def getEnsembleTreeVars( ENSTREE, varNames ) :
   importance = ENSTREE.feature_importances_
   index = np.argsort(importance)
   theList = []
   for i in index :
       imp_val = importance[i]
       if imp_val > np.average( ENSTREE.feature_importances_ ) :
           v = int( imp_val / np.max( ENSTREE.feature_importances_ ) * 100 )
           theList.append( ( varNames[i], v ) )
   theList = sorted(theList,key=itemgetter(1),reverse=True)
   return theList


feature_cols = list( X.columns.values )
vars_RF_flag = getEnsembleTreeVars( fm01_RF, feature_cols )

for i in vars_RF_flag :
   print( i )
```

```
('M_DEBTINC', 100)
('IMP_DEBTINC', 68)
('IMP_CLAGE', 43)
('IMP_DELINQ', 39)
('Unnamed: 0', 33)
('IMP_VALUE', 33)
('IMP_MORTDUE', 31)
('IMP_CLNO', 31)
('LOAN', 27)
('IMP_YOJ', 25)
('IMP_DEROG', 21)
```

In [43]:
```
loss_m01_RF = RandomForestRegressor(n_estimators = 100, random_state=1)
loss_m01_RF = loss_m01_RF.fit( W_train, Z_train[LOSS] )

L_Pred_train = loss_m01_RF.predict(W_train)
L_Pred_test = loss_m01_RF.predict(W_test)

RMSE_TRAIN = math.sqrt( metrics.mean_squared_error(Z_train[LOSS], L_Pred_train))
RMSE_TEST = math.sqrt( metrics.mean_squared_error(Z_test[LOSS], L_Pred_test))

print("RF RMSE Train:", RMSE_TRAIN )
print("RF RMSE Test:", RMSE_TEST )

RMSE_RF = RMSE_TEST

feature_cols = list( X.columns.values )
vars_RF_amt = getEnsembleTreeVars( loss_m01_RF, feature_cols )

for i in vars_RF_amt :
   print( i )
```

```
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
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C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if not hasattr(array, "sparse") and array.dtypes.apply(is_sparse).any():
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
RF RMSE Train: 1070.6050159372307
RF RMSE Test: 2866.360580467834
('Unnamed: 0', 100)
('M_DEBTINC', 87)
('IMP_DEBTINC', 40)
('IMP_DELINQ', 38)
('IMP_CLAGE', 27)
('IMP_CLNO', 22)
('IMP_VALUE', 18)
('LOAN', 17)
('IMP_YOJ', 17)
```

Gradient Boosting

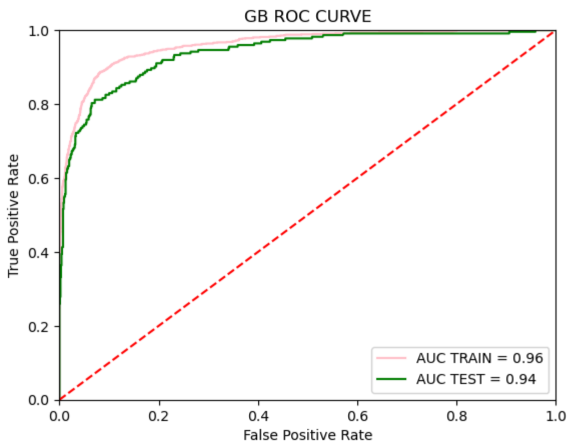
In [44]:
```
fm01_GB = GradientBoostingClassifier( random_state=1 )
fm01_GB = fm01_GB.fit( X_train, Y_train[ FLAG ] )

Y_Pred_train = fm01_GB.predict(X_train)
Y_Pred_test = fm01_GB.predict(X_test)

print("\n=============\n")
print("GRADIENT BOOSTING\n")
print("Probability of default")
print("Accuracy Train:",metrics.accuracy_score(Y_train[FLAG], Y_Pred_train))
print("Accuracy Test:",metrics.accuracy_score(Y_test[FLAG], Y_Pred_test))
print("\n")
```

```
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if not hasattr(array, "sparse") and array.dtypes.apply(is_sparse).any():
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
=============

GRADIENT BOOSTING

Probability of default
Accuracy Train: 0.9221895973154363
Accuracy Test: 0.9161073825503355
```

```
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if not hasattr(array, "sparse") and array.dtypes.apply(is_sparse).any():
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if not hasattr(array, "sparse") and array.dtypes.apply(is_sparse).any():
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
```

In [45]:
```python
probs = fm01_GB.predict_proba(X_train)
p1 = probs[:,1]
fpr_train, tpr_train, threshold = metrics.roc_curve( Y_train[FLAG], p1)
roc_auc_train = metrics.auc(fpr_train, tpr_train)

probs = fm01_GB.predict_proba(X_test)
p1 = probs[:,1]
fpr_test, tpr_test, threshold = metrics.roc_curve( Y_test[FLAG], p1)
roc_auc_test = metrics.auc(fpr_test, tpr_test)

fpr_GB = fpr_test
tpr_GB = tpr_test
auc_GB = roc_auc_test


feature_cols = list( X.columns.values )
vars_GB_flag = getEnsembleTreeVars( fm01_GB, feature_cols )


for i in vars_GB_flag :
   print(i)



plt.title('GB ROC CURVE')
plt.plot(fpr_train, tpr_train, label = 'AUC TRAIN = %0.2f' % roc_auc_train, color="PINK")
plt.plot(fpr_test, tpr_test, label = 'AUC TEST = %0.2f' % roc_auc_test, color="GREEN")
plt.legend(loc = 'lower right')
plt.plot([0, 1], [0, 1],'r--')
plt.xlim([0, 1])
plt.ylim([0, 1])
plt.ylabel('True Positive Rate')
plt.xlabel('False Positive Rate')
plt.show()
```

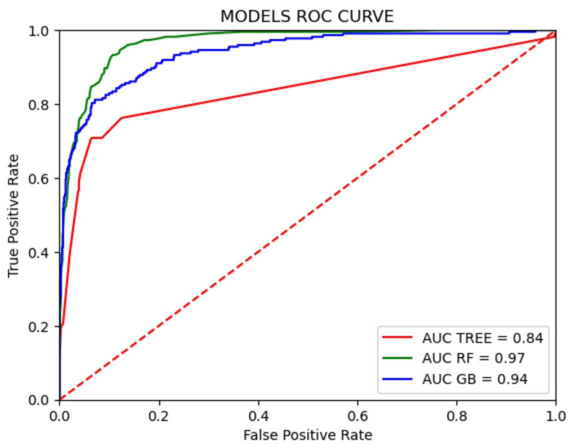
```
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if not hasattr(array, "sparse") and array.dtypes.apply(is_sparse).any():
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if not hasattr(array, "sparse") and array.dtypes.apply(is_sparse).any():
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
('M_DEBTINC', 100)
('IMP_DEBTINC', 29)
('IMP_DELINQ', 18)
('IMP_CLAGE', 16)
('IMP_DEROG', 9)
('M_VALUE', 8)
```



In [46]:
```
#Loss amount
loss_m01_GB = GradientBoostingRegressor(random_state=1)
loss_m01_GB = loss_m01_GB.fit( W_train, Z_train[LOSS] )

Z_Pred_train = loss_m01_GB.predict(W_train)
Z_Pred_test = loss_m01_GB.predict(W_test)

RMSE_TRAIN = math.sqrt( metrics.mean_squared_error(Z_train[LOSS], Z_Pred_train))
RMSE_TEST = math.sqrt( metrics.mean_squared_error(Z_test[LOSS], Z_Pred_test))

print("GB RMSE Train:", RMSE_TRAIN )
print("GB RMSE Test:", RMSE_TEST )

RMSE_GB = RMSE_TEST

feature_cols = list( X.columns.values )
vars_GB_amt = getEnsembleTreeVars( loss_m01_GB, feature_cols )


for i in vars_GB_amt :
   print(i)
```

```
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
instead.
  if not hasattr(array, "sparse") and array.dtypes.apply(is_sparse).any():
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
GB RMSE Train: 2518.545366448028
GB RMSE Test: 2853.468706094007
('M_DEBTINC', 100)
('Unnamed: 0', 99)
('IMP_DELINQ', 46)
('IMP_DEBTINC', 39)
('IMP_CLAGE', 16)
('IMP_DEROG', 14)
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
instead.
  if not hasattr(array, "sparse") and array.dtypes.apply(is_sparse).any():
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
instead.
  if not hasattr(array, "sparse") and array.dtypes.apply(is_sparse).any():
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
```

In [47]:
```
plt.title('MODELS ROC CURVE')
plt.plot(fpr_tree, tpr_tree, label = 'AUC TREE = %0.2f' % auc_tree, color="red")
plt.plot(fpr_RF, tpr_RF, label = 'AUC RF = %0.2f' % auc_RF, color="green")
plt.plot(fpr_GB, tpr_GB, label = 'AUC GB = %0.2f' % auc_GB, color="blue")
plt.legend(loc = 'lower right')
plt.plot([0, 1], [0, 1],'r--')
plt.xlim([0, 1])
plt.ylim([0, 1])
plt.ylabel('True Positive Rate')
plt.xlabel('False Positive Rate')
plt.show()



print("Root Mean Square Average For Damages")
print("TREE", RMSE_TREE)
print("RF", RMSE_RF)
print("GB", RMSE_GB)
```



```
Root Mean Square Average For Damages
TREE 3399.6077841389447
RF 2866.360580467834
GB 2853.468706094007
```

In [49]:
```
# split by data type and print out variables
dt = cleandf01.dtypes
numList = []
for i in dt.index :
    #print(i, dt[i])
    if i in ( [ FLAG, LOSS ] ) : continue
    if dt[i] in (["float64","int64"]) : numList.append( i )
```

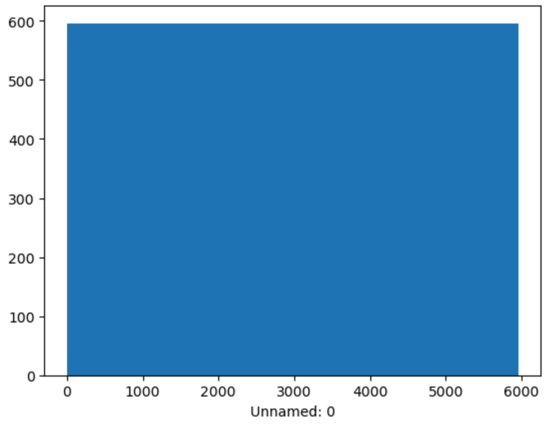
```
for i in numList:
    print(i)


# %%
print(" number ")
print(" ----- ")
for i in numList:
    print( cleandf01[i]. describe() )
    print( " -------\n ")

# %%
for i in numList :
    print( i )
    plt.hist ( cleandf01[ i ])
    plt.xlabel ( i )
    plt.show()


for i in numList :
    theMean = df[i].mean()
    theSD = df[i].std()
    theMax = df[i].max()
    theCutoff = round( theMean + 3*theSD )
    if theMax < theCutoff : continue
    #flag if you fixed an outlier
    FLAG = "O_" + i
    TRUNC = "TRUNC_" + i
    df[ FLAG ] = ( cleandf01[i] > theCutoff )+ 0
    df[ TRUNC ] = df[ i ]
    df.loc[ df[TRUNC] > theCutoff, TRUNC ] = theCutoff
    df = df.drop( i, axis=1 )


dt = df.dtypes
numList = []
for i in dt.index :
    if i in ( [ FLAG, LOSS ] ) : continue
    if dt[i] in (["float64","int64"]) : numList.append( i )

for i in numList:
    print(i)

# %%
print(" number ")
print(" ----- ")
for i in numList:
    print( cleandf01[i]. describe() )
    print( " -------\n ")

# %%
for i in numList :
    print( i )
    plt.hist ( cleandf01[ i ])
    plt.xlabel ( i )
    plt.show()
```

```
Unnamed: 0
LOAN
OHE_REASON_HOMEIMP
OHE_REASON_DEBTCON
OHE_REASON_MISSING
OHE_JOB_OFFICE
OHE_JOB_OTHER
OHE_JOB_MGR
OHE_JOB_PROFEXEC
OHE_JOB_SALES
M_MORTDUE
IMP_MORTDUE
M_VALUE
IMP_VALUE
M_YOJ
IMP_YOJ
M_DEROG
IMP_DEROG
M_DELINQ
IMP_DELINQ
M_CLAGE
IMP_CLAGE
M_NINQ
IMP_NINQ
M_CLNO
IMP_CLNO
M_DEBTINC
IMP_DEBTINC
 number
 -----
count    5960.000000
mean     2979.500000
std      1720.648134
min         0.000000
25%      1489.750000
50%      2979.500000
75%      4469.250000
max      5959.000000
Name: Unnamed: 0, dtype: float64
 -------

count     5960.000000
mean     18607.969799
std      11207.480417
min       1100.000000
25%      11100.000000
50%      16300.000000
75%      23300.000000
max      89900.000000
Name: LOAN, dtype: float64
 -------

count    5960.000000
mean        0.298658
std         0.457708
min         0.000000
25%         0.000000
50%         0.000000
75%         1.000000
max         1.000000
Name: OHE_REASON_HOMEIMP, dtype: float64
 -------

count    5960.000000
mean        0.659060
std         0.474065
min         0.000000
25%         0.000000
50%         1.000000
75%         1.000000
max         1.000000
Name: OHE_REASON_DEBTCON, dtype: float64
 -------

count    5960.000000
mean        0.042282
std         0.201248
min         0.000000
25%         0.000000
50%         0.000000
75%         0.000000
max         1.000000
Name: OHE_REASON_MISSING, dtype: float64
 -------

count    5960.000000
mean        0.159060
std         0.365763
min         0.000000
25%         0.000000
50%         0.000000
75%         0.000000
max         1.000000
Name: OHE_JOB_OFFICE, dtype: float64
 -------

count    5960.000000
mean        0.400671
std         0.490076
min         0.000000
25%         0.000000
50%         0.000000
75%         1.000000
max         1.000000
Name: OHE_JOB_OTHER, dtype: float64
 -------

count    5960.000000
mean        0.128691
std         0.334886
min         0.000000
25%         0.000000
```

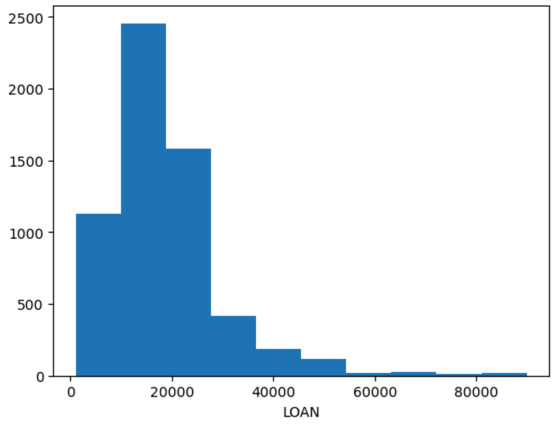
```
50%         0.000000
75%         0.000000
max         1.000000
Name: OHE_JOB_MGR, dtype: float64
 -------

count    5960.0
mean        0.0
std         0.0
min         0.0
25%         0.0
50%         0.0
75%         0.0
max         0.0
Name: OHE_JOB_PROFEXEC, dtype: float64
 -------

count    5960.000000
mean        0.018289
std         0.134004
min         0.000000
25%         0.000000
50%         0.000000
75%         0.000000
max         1.000000
Name: OHE_JOB_SALES, dtype: float64
 -------

count    5960.000000
mean        0.086913
std         0.281731
min         0.000000
25%         0.000000
50%         0.000000
75%         0.000000
max         1.000000
Name: M_MORTDUE, dtype: float64
 -------

count      5960.000000
mean      73001.041812
std       42552.726779
min        2063.000000
25%       48139.000000
50%       65019.000000
75%       88200.250000
max      399550.000000
Name: IMP_MORTDUE, dtype: float64
 -------

count    5960.000000
mean        0.018792
std         0.135801
min         0.000000
25%         0.000000
50%         0.000000
75%         0.000000
max         1.000000
Name: M_VALUE, dtype: float64
 -------

count      5960.000000
mean     101540.387423
std       56869.436682
min        8000.000000
25%       66489.500000
50%       89235.500000
75%      119004.750000
max      855909.000000
Name: IMP_VALUE, dtype: float64
 -------

count    5960.000000
mean        0.086409
std         0.280991
min         0.000000
25%         0.000000
50%         0.000000
75%         0.000000
max         1.000000
Name: M_YOJ, dtype: float64
 -------

count    5960.000000
mean        8.756166
std         7.259424
min         0.000000
25%         3.000000
50%         7.000000
75%        12.000000
max        41.000000
Name: IMP_YOJ, dtype: float64
 -------

count    5960.000000
mean        0.118792
std         0.323571
min         0.000000
25%         0.000000
50%         0.000000
75%         0.000000
max         1.000000
Name: M_DEROG, dtype: float64
 -------

count    5960.000000
mean        0.224329
std         0.798458
min         0.000000
25%         0.000000
50%         0.000000
75%         0.000000
```

```
max        10.000000
Name: IMP_DEROG, dtype: float64
 -------

count    5960.000000
mean        0.097315
std         0.296412
min         0.000000
25%         0.000000
50%         0.000000
75%         0.000000
max         1.000000
Name: M_DELINQ, dtype: float64
 -------

count    5960.000000
mean        0.405705
std         1.079256
min         0.000000
25%         0.000000
50%         0.000000
75%         0.000000
max        15.000000
Name: IMP_DELINQ, dtype: float64
 -------

count    5960.000000
mean        0.051678
std         0.221394
min         0.000000
25%         0.000000
50%         0.000000
75%         0.000000
max         1.000000
Name: M_CLAGE, dtype: float64
 -------

count    5960.000000
mean      179.440725
std        83.574697
min         0.000000
25%       117.371430
50%       173.466667
75%       227.143058
max      1168.233561
Name: IMP_CLAGE, dtype: float64
 -------

count    5960.000000
mean        0.085570
std         0.279752
min         0.000000
25%         0.000000
50%         0.000000
75%         0.000000
max         1.000000
Name: M_NINQ, dtype: float64
 -------

count    5960.000000
mean        1.170134
std         1.653866
min         0.000000
25%         0.000000
50%         1.000000
75%         2.000000
max        17.000000
Name: IMP_NINQ, dtype: float64
 -------

count    5960.000000
mean        0.037248
std         0.189386
min         0.000000
25%         0.000000
50%         0.000000
75%         0.000000
max         1.000000
Name: M_CLNO, dtype: float64
 -------

count    5960.000000
mean       21.247819
std         9.951308
min         0.000000
25%        15.000000
50%        20.000000
75%        26.000000
max        71.000000
Name: IMP_CLNO, dtype: float64
 -------

count    5960.000000
mean        0.212584
std         0.409170
min         0.000000
25%         0.000000
50%         0.000000
75%         0.000000
max         1.000000
Name: M_DEBTINC, dtype: float64
 -------

count    5960.000000
mean       34.000651
std         7.644528
min         0.524499
25%        30.763159
50%        34.818262
75%        37.949892
max       203.312149
Name: IMP_DEBTINC, dtype: float64
```

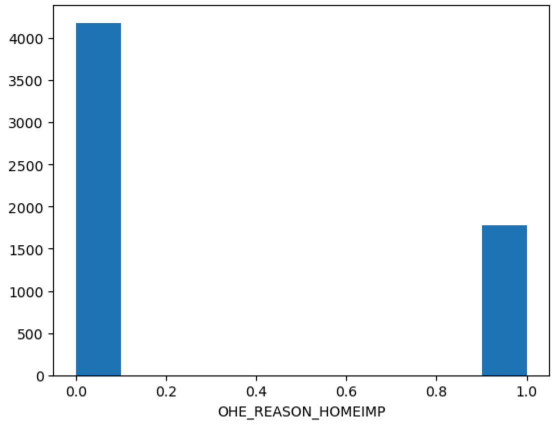
```
-------

Unnamed: 0
```



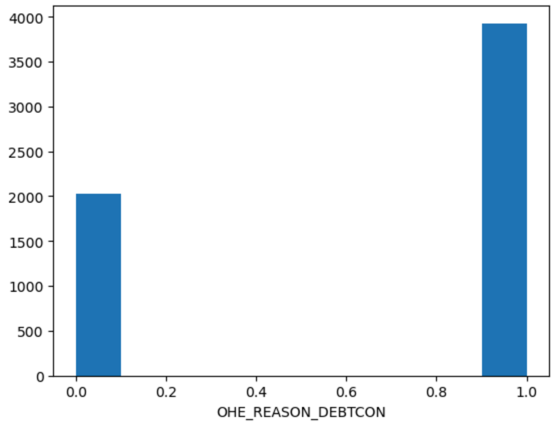
```
LOAN
```



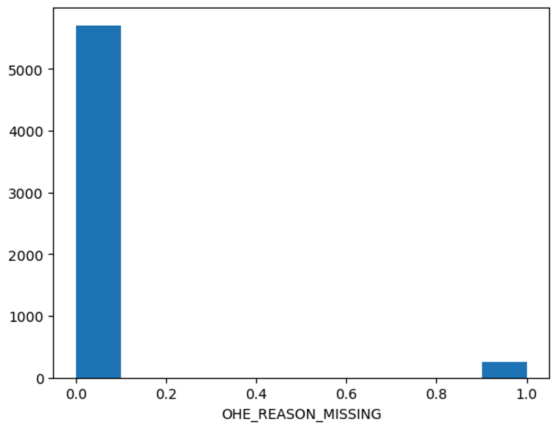
```
OHE_REASON_HOMEIMP
```



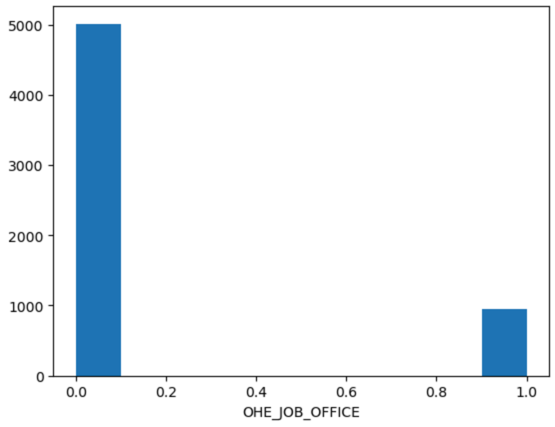
```
OHE_REASON_DEBTCON
```



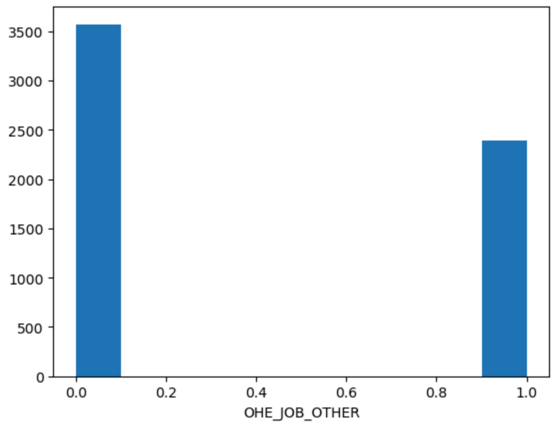
```
OHE_REASON_MISSING
```



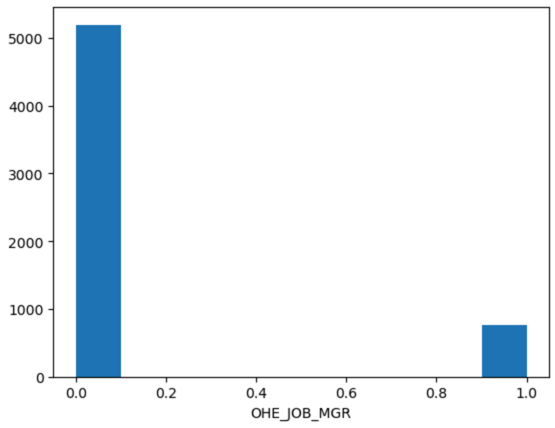
```
OHE_JOB_OFFICE
```



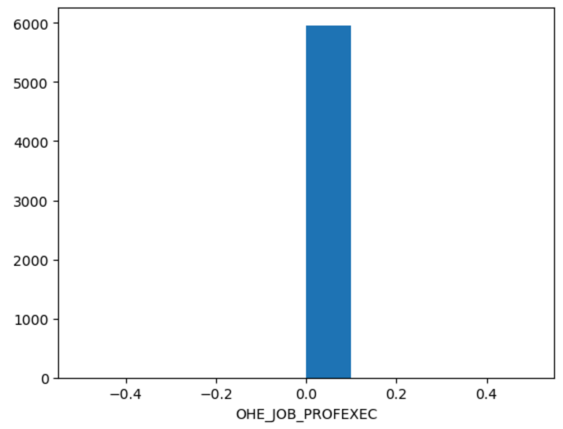
```
OHE_JOB_OTHER
```



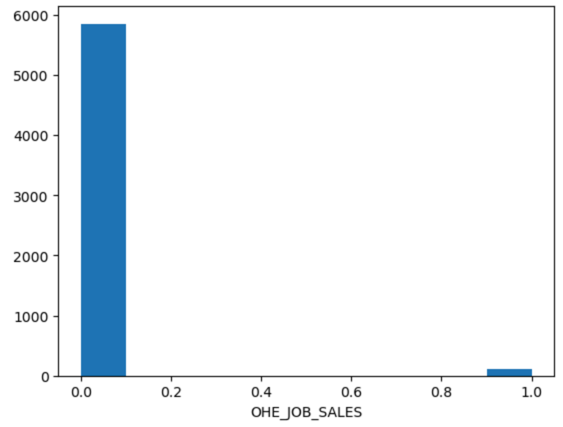
```
OHE_JOB_MGR
```



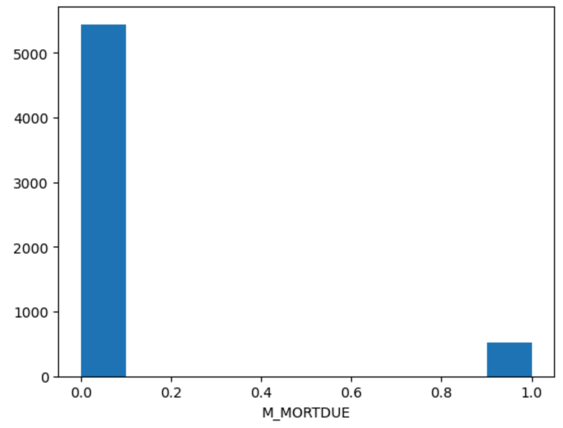
```
OHE_JOB_PROFEXEC
```



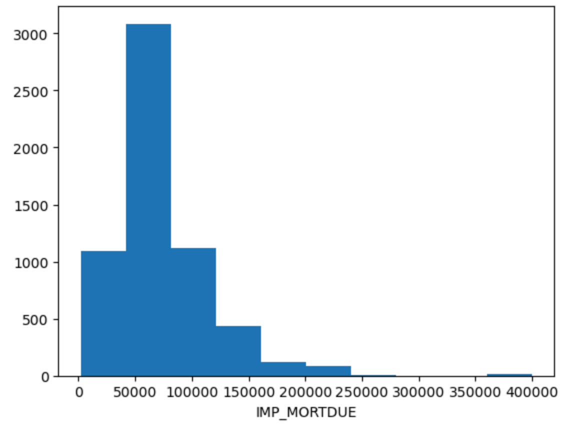
```
OHE_JOB_SALES
```



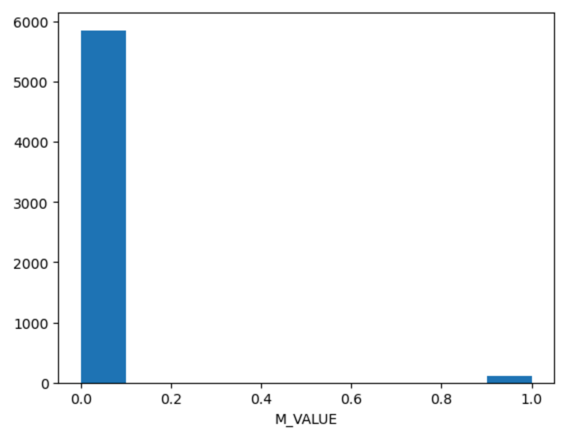
```
M_MORTDUE
```



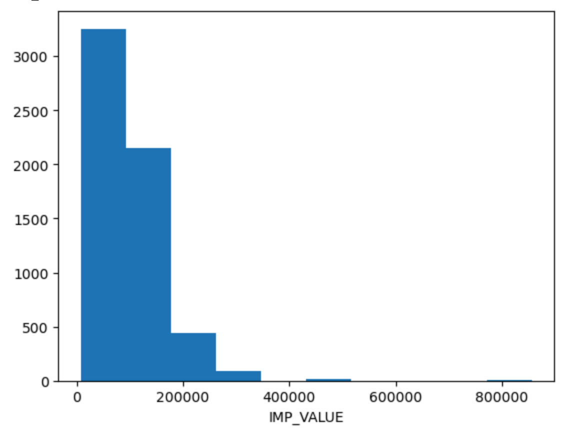
```
IMP_MORTDUE
```



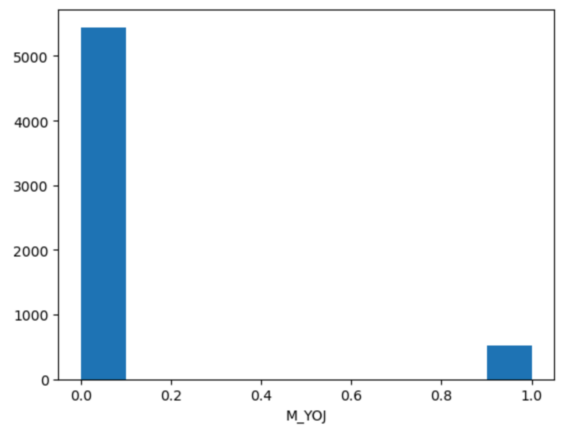
```
M_VALUE
```



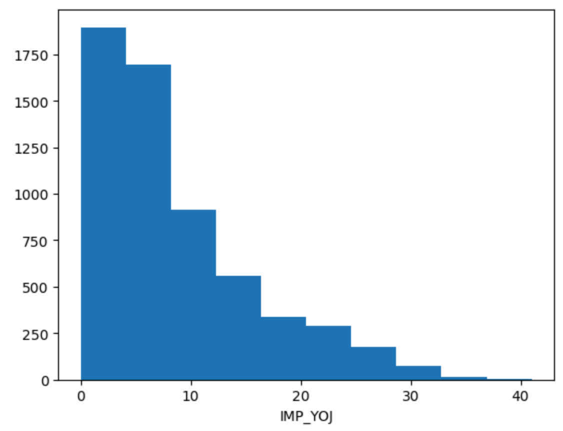
IMP_VALUE



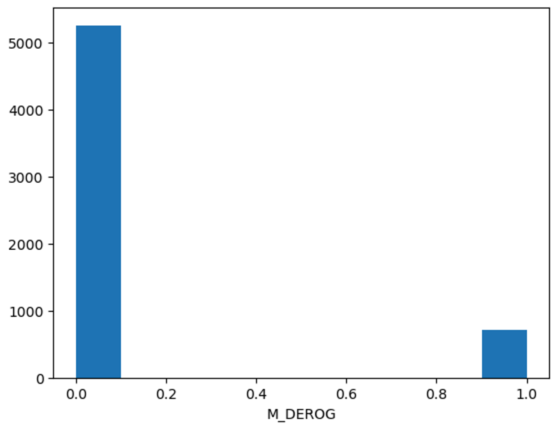
M_YOJ



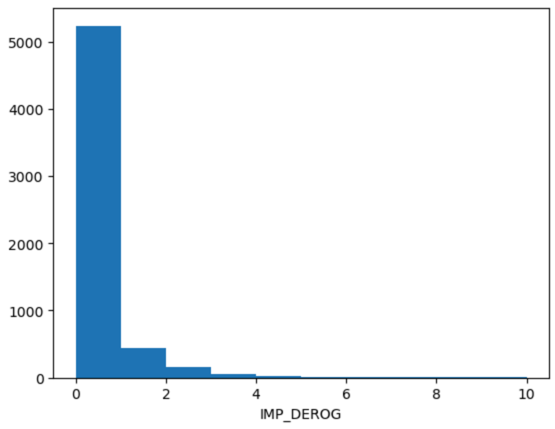
IMP_YOJ



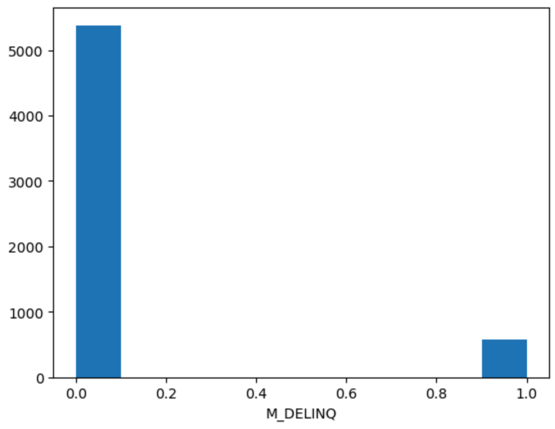
M_DEROG



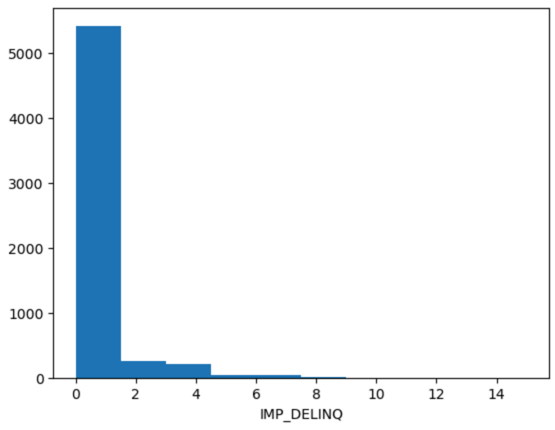
```
IMP_DEROG
```



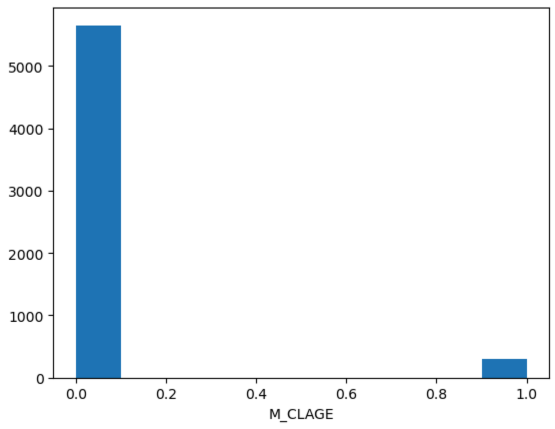
```
M_DELINQ
```



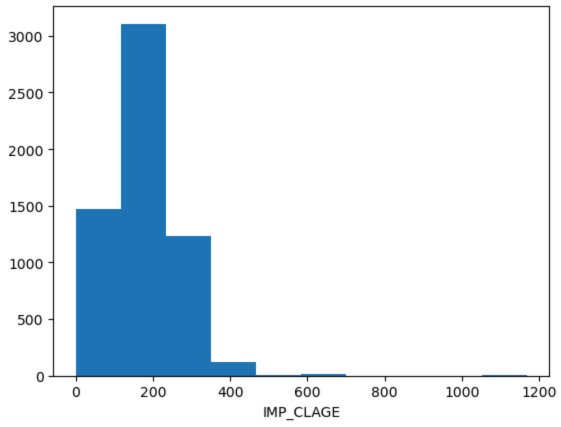
```
IMP_DELINQ
```



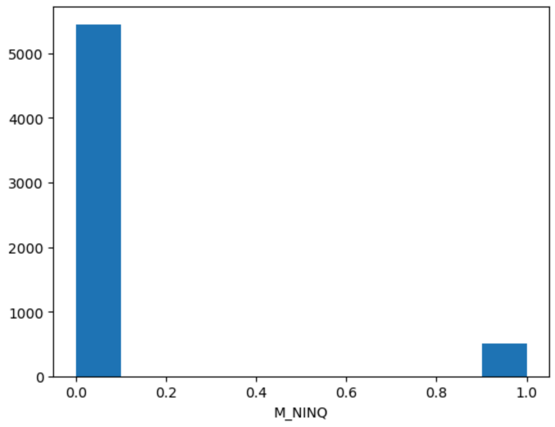
```
M_CLAGE
```



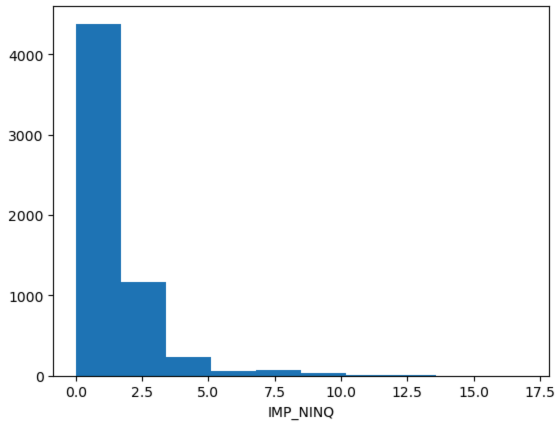
```
IMP_CLAGE
```



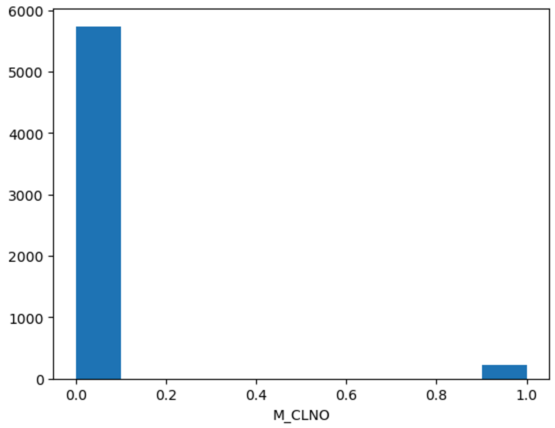
```
M_NINQ
```



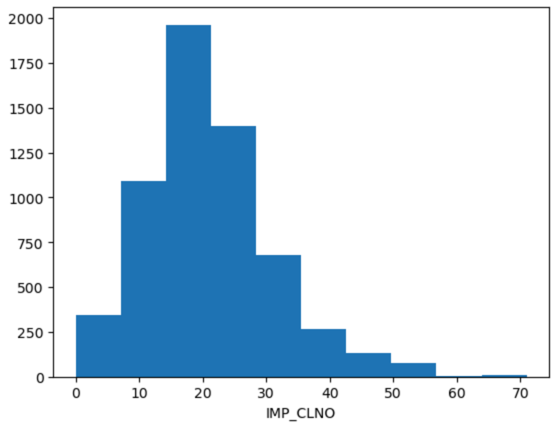
```
IMP_NINQ
```



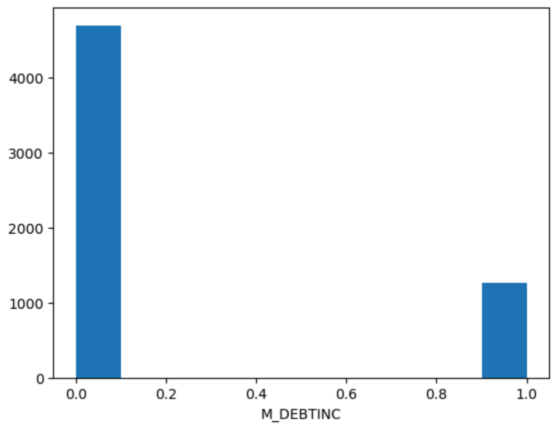
```
M_CLNO
```



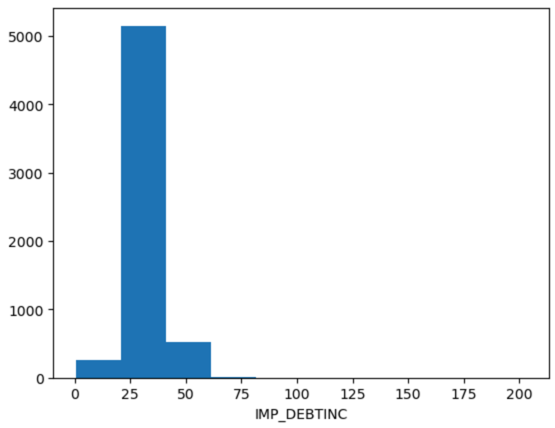
IMP_CLNO



M_DEBTINC



IMP_DEBTINC



```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
Cell In[49], line 29
     25     plt.show()
     28 for i in numList :
---> 29     theMean = df[i].mean()
     30     theSD = df[i].std()
     31     theMax = df[i].max()

NameError: name 'df' is not defined
```

In [50]:
```
def getProbAccuracyScores( NAME, MODEL, X, Y ) :
    pred = MODEL.predict( X )
    probs = MODEL.predict_proba( X )
    acc_score = metrics.accuracy_score(Y, pred)
    p1 = probs[:,1]
    fpr, tpr, threshold = metrics.roc_curve( Y, p1)
    auc = metrics.auc(fpr,tpr)
    return [NAME, acc_score, fpr, tpr, auc]

def print_ROC_Curve( TITLE, LIST ) :
    fig = plt.figure(figsize=(6,4))
    plt.title( TITLE )
    for theResults in LIST :
        NAME = theResults[0]
        fpr = theResults[2]
        tpr = theResults[3]
        auc = theResults[4]
        theLabel = "AUC " + NAME + ' %0.2f' % auc
        plt.plot(fpr, tpr, label = theLabel )
    plt.legend(loc = 'lower right')
    plt.plot([0, 1], [0, 1],'r--')
    plt.xlim([0, 1])
    plt.ylim([0, 1])
    plt.ylabel('True Positive Rate')
    plt.xlabel('False Positive Rate')
    plt.show()


def print_Accuracy( TITLE, LIST ) :
    print( TITLE )
    print( "======" )
    for theResults in LIST :
        NAME = theResults[0]
        ACC = theResults[1]
        print( NAME, " = ", ACC )
    print( "------\n\n" )

def getAmtAccuracyScores( NAME, MODEL, X, Y ) :
    pred = MODEL.predict( X )
    MEAN = Y.mean()
    RMSE = math.sqrt( metrics.mean_squared_error( Y, pred))
    return [NAME, RMSE, MEAN]
```

In [53]:
```
WHO = "TREE"

CLM = tree.DecisionTreeClassifier( max_depth=4 )
CLM = CLM.fit( X_train, Y_train[ FLAG ] )

TRAIN_CLM = getProbAccuracyScores( WHO + "_Train", CLM, X_train, Y_train[ FLAG ] )
TEST_CLM = getProbAccuracyScores( WHO, CLM, X_test, Y_test[ FLAG ] )

print_ROC_Curve( WHO, [ TRAIN_CLM, TEST_CLM ] )
print_Accuracy( WHO + " CLASSIFICATION ACCURACY", [ TRAIN_CLM, TEST_CLM ] )

feature_cols = list( X.columns.values )
tree.export_graphviz(CLM,out_file='tree_f.txt',filled=True, rounded=True, feature_names = feature_cols, impurity=False, class_names=["Good","Bad"]  )
vars_tree_flag = getTreeVars( CLM, feature_cols )


print_Accuracy( " CLASSIFICATION ACCURACY ", [TRAIN_CLM, TEST_CLM])



feature_cols = list( X.columns.values )
tree.export_graphviz(CLM,out_file='NEWtree_f.txt',filled=True, rounded=True, feature_names = feature_cols, impurity=False, class_names=["Good","Bad"]  )
vars_tree_flag = getTreeVars( CLM, feature_cols)
```

```
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if not hasattr(array, "sparse") and array.dtypes.apply(is_sparse).any():
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if not hasattr(array, "sparse") and array.dtypes.apply(is_sparse).any():
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if not hasattr(array, "sparse") and array.dtypes.apply(is_sparse).any():
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:605: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype):
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```

```
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instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
```

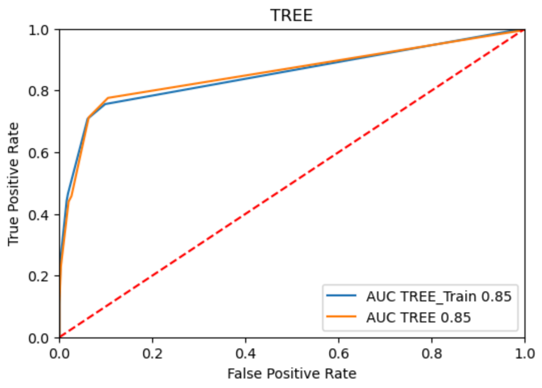

```
TREE CLASSIFICATION ACCURACY
======
TREE_Train  =  0.8926174496644296
TREE  =  0.8951342281879194
------


 CLASSIFICATION ACCURACY
======
TREE_Train  =  0.8926174496644296
TREE  =  0.8951342281879194
------
```

In [55]:
```python
AMT = tree.DecisionTreeRegressor( max_depth= 4 )
AMT = AMT.fit( W_train, Z_train[LOSS] )

TRAIN_AMT = getAmtAccuracyScores( WHO + "_Train", AMT, W_train, Z_train[LOSS] )
TEST_AMT = getAmtAccuracyScores( WHO, AMT, W_test, Z_test[LOSS] )
#print_Accuracy( WHO + " RMSE ACCURACY", [ TRAIN_AMT, TEST_AMT ] )

feature_cols = list( X.columns.values )
vars_tree_amt = getTreeVars( AMT, feature_cols )
tree.export_graphviz(AMT,out_file='tree_a.txt',filled=True, rounded=True, feature_names = feature_cols, impurity=False, precision=0  )


TREE_CLM = TEST_CLM.copy()
TREE_AMT = TEST_AMT.copy()
```

```
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
instead.
  if not hasattr(array, "sparse") and array.dtypes.apply(is_sparse).any():
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instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
```

In [56]:
```python
def getEnsembleTreeVars( ENSTREE, varNames ) :
    importance = ENSTREE.feature_importances_
    index = np.argsort(importance)
    theList = []
    for i in index :
        imp_val = importance[i]
        if imp_val > np.average( ENSTREE.feature_importances_ ) :
            v = int( imp_val / np.max( ENSTREE.feature_importances_ ) * 100 )
            theList.append( ( varNames[i], v ) )
    theList = sorted(theList,key=itemgetter(1),reverse=True)
    return theList
```

In [57]:
```
WHO = "RF"

CLM = RandomForestClassifier( n_estimators = 25, random_state=1 )
CLM = CLM.fit( X_train, Y_train[ FLAG ] )

TRAIN_CLM = getProbAccuracyScores( WHO + "_Train", CLM, X_train, Y_train[ FLAG ] )
TEST_CLM = getProbAccuracyScores( WHO, CLM, X_test, Y_test[ FLAG ] )

print_ROC_Curve( WHO, [ TRAIN_CLM, TEST_CLM ] )
print_Accuracy( WHO + " CLASSIFICATION ACCURACY", [ TRAIN_CLM, TEST_CLM ] )


feature_cols = list( X.columns.values )
vars_RF_flag = getEnsembleTreeVars( CLM, feature_cols )
```

```
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
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```

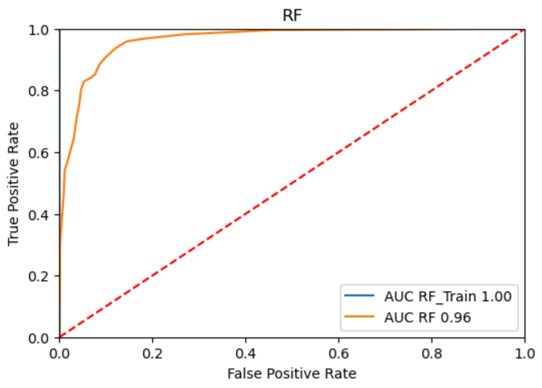

```
RF CLASSIFICATION ACCURACY
======
RF_Train  =  0.9993708053691275
RF  =  0.9161073825503355
------
```

In [58]:
```python
AMT = RandomForestRegressor(n_estimators = 100, random_state=1)
AMT = AMT.fit( W_train, Z_train[LOSS] )

TRAIN_AMT = getAmtAccuracyScores( WHO + "_Train", AMT, W_train, Z_train[LOSS] )
TEST_AMT = getAmtAccuracyScores( WHO, AMT, W_test, Z_test[LOSS] )
print_Accuracy( WHO + " RMSE ACCURACY", [ TRAIN_AMT, TEST_AMT ] )

feature_cols = list( X.columns.values )
vars_RF_amt = getEnsembleTreeVars( AMT, feature_cols )

for i in vars_RF_amt :
   print( i )

RF_CLM = TEST_CLM.copy()
RF_AMT = TEST_AMT.copy()
```

```
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
instead.
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instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
```

```
RF RMSE ACCURACY
======
RF_Train  =  1070.6050159372307
RF  =  2866.360580467834
------


('Unnamed: 0', 100)
('M_DEBTINC', 87)
('IMP_DEBTINC', 40)
('IMP_DELINQ', 38)
('IMP_CLAGE', 27)
('IMP_CLNO', 22)
('IMP_VALUE', 18)
('LOAN', 17)
('IMP_YOJ', 17)
```

In [59]:
```
WHO = "GB"

CLM = GradientBoostingClassifier( random_state=1 )
CLM = CLM.fit( X_train, Y_train[ FLAG ] )

TRAIN_CLM = getProbAccuracyScores( WHO + "_Train", CLM, X_train, Y_train[ FLAG ] )
TEST_CLM = getProbAccuracyScores( WHO, CLM, X_test, Y_test[ FLAG] )

print_ROC_Curve( WHO, [ TRAIN_CLM, TEST_CLM ] )
print_Accuracy( WHO + " CLASSIFICATION ACCURACY", [ TRAIN_CLM, TEST_CLM ] )


feature_cols = list( X.columns.values )
vars_GB_flag = getEnsembleTreeVars( CLM, feature_cols )
```

```
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` 
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```

```
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```

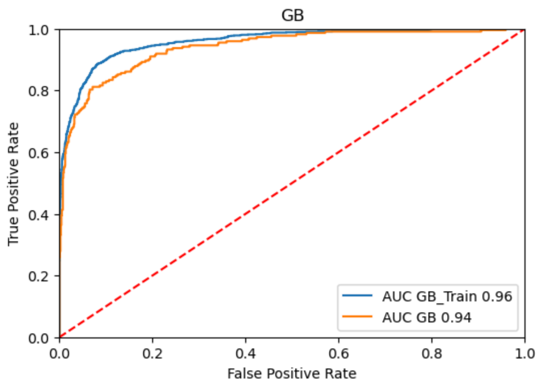

```
GB CLASSIFICATION ACCURACY
======
GB_Train  =  0.9221895973154363
GB  =  0.9161073825503355
------
```

In [60]:
```python
AMT = GradientBoostingRegressor(random_state=1)
AMT = AMT.fit( W_train, Z_train[LOSS] )

TRAIN_AMT = getAmtAccuracyScores( WHO + "_Train", AMT, W_train, Z_train[LOSS] )
TEST_AMT = getAmtAccuracyScores( WHO, AMT, W_test, Z_test[LOSS] )
print_Accuracy( WHO + " RMSE ACCURACY", [ TRAIN_AMT, TEST_AMT ] )

feature_cols = list( X.columns.values )
vars_GB_amt = getEnsembleTreeVars( AMT, feature_cols )

for i in vars_GB_amt :
   print( i )

GB_CLM = TEST_CLM.copy()
GB_AMT = TEST_AMT.copy()
```

```
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
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C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:614: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)` instead.
  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
GB RMSE ACCURACY
======
GB_Train  =  2518.545366448028
GB  =  2853.468706094007
------


('M_DEBTINC', 100)
('Unnamed: 0', 99)
('IMP_DELINQ', 46)
('IMP_DEBTINC', 39)
('IMP_CLAGE', 16)
('IMP_DEROG', 14)
```

```
C:\Anaconda\Lib\site-packages\sklearn\utils\validation.py:767: FutureWarning: is_sparse is deprecated and will be removed in a future version. Check `isinstance(dtype, pd.SparseDtype)`
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  if is_sparse(pd_dtype) or not is_extension_array_dtype(pd_dtype):
```

```
In [ ]:
```