```
import numpy as np
import pandas as pd
import scipy.stats
import matplotlib.pyplot as plt
import seaborn as sns
import statsmodels.api as sm
from statsmodels.formula.api import ols
from statsmodels.stats.multicomp import pairwise_tukeyhsd
from scipy.stats import chi2_contingency


from google.colab import files
uploaded= files.upload()
```

Choose Files No file chosen Upload widget is only available when the cell has been executed in the current browser session. Please rerun this cell to enable.

```
Saving Machine_EDA.csv to Machine_EDA.csv
```

```
df= pd.read_csv("Machine_EDA.csv")


df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 8 columns):
 #   Column            Non-Null Count  Dtype  
---  ------            --------------  -----  
 0   Type              10000 non-null  object 
 1   Air_temp          10000 non-null  float64
 2   Process_temp      10000 non-null  float64
 3   Rotational_speed  10000 non-null  float64
 4   Torque            10000 non-null  float64
 5   Tool_wear         10000 non-null  int64  
 6   Target            10000 non-null  int64  
 7   Failure_Type      10000 non-null  object 
dtypes: float64(4), int64(2), object(2)
memory usage: 625.1+ KB
```

```
df1= df[:]


df1.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 8 columns):
 #   Column            Non-Null Count  Dtype  
---  ------            --------------  -----  
 0   Type              10000 non-null  object 
 1   Air_temp          10000 non-null  float64
 2   Process_temp      10000 non-null  float64
 3   Rotational_speed  10000 non-null  float64
 4   Torque            10000 non-null  float64
 5   Tool_wear         10000 non-null  int64
```

```
 6   Target           10000 non-null  int64
 7   Failure_Type     10000 non-null  object
dtypes: float64(4), int64(2), object(2)
memory usage: 625.1+ KB
```

```
#Creating Dummies of Categorical Variables and dropping 1st dummy variable

Catg_vars =['Type', 'Failure_Type']


for i in Catg_vars:
    Catg_list = 'var'+'_'+i
    Catg_list = pd.get_dummies(df[i], drop_first=True, prefix = i)
    df2 = df1.join(Catg_list)
    df1 = df2


df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 8 columns):
 #   Column           Non-Null Count  Dtype
---  ------           --------------  -----
 0   Type             10000 non-null  object
 1   Air_temp         10000 non-null  float64
 2   Process_temp     10000 non-null  float64
 3   Rotational_speed  10000 non-null  float64
 4   Torque           10000 non-null  float64
 5   Tool_wear        10000 non-null  int64
 6   Target           10000 non-null  int64
 7   Failure_Type     10000 non-null  object
dtypes: float64(4), int64(2), object(2)
memory usage: 625.1+ KB
```

```
df1.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 10 columns):
 #   Column                       Non-Null Count  Dtype
---  ------                       --------------  -----
 0   Type                         10000 non-null  object
 1   Air_temp                     10000 non-null  float64
 2   Process_temp                 10000 non-null  float64
 3   Rotational_speed             10000 non-null  float64
 4   Torque                       10000 non-null  float64
 5   Tool_wear                    10000 non-null  int64
 6   Target                       10000 non-null  int64
 7   Failure_Type                 10000 non-null  object
 8   Type_L                       10000 non-null  uint8
 9   Failure_Type_Random Failures  10000 non-null  uint8
dtypes: float64(4), int64(2), object(2), uint8(2)
memory usage: 644.7+ KB
```

```
df2.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 10 columns):
 #   Column                          Non-Null Count  Dtype
---  ------                          --------------  -----
 0   Type                            10000 non-null  object
 1   Air_temp                        10000 non-null  float64
 2   Process_temp                    10000 non-null  float64
 3   Rotational_speed                10000 non-null  float64
 4   Torque                          10000 non-null  float64
 5   Tool_wear                       10000 non-null  int64
 6   Target                          10000 non-null  int64
 7   Failure_Type                    10000 non-null  object
 8   Type_L                          10000 non-null  uint8
 9   Failure_Type_Random Failures  10000 non-null  uint8
dtypes: float64(4), int64(2), object(2), uint8(2)
memory usage: 644.7+ KB
```

```
#After Creating dummies and dropping 1st dummy now drop original variable
Catg_vars = ['Type', 'Failure_Type']
```

```
df_vars = df1.columns.values.tolist()
```

```
to_keep = [i for i in df_vars if i not in Catg_vars]
# keep only those which are not in the list of data_vars
```

```
df_final = df1[to_keep]
```

```
df_final.columns.values
```

```
array(['Air_temp', 'Process_temp', 'Rotational_speed', 'Torque',
       'Tool_wear', 'Target', 'Type_L', 'Failure_Type_Random Failures'],
      dtype=object)
```

```
df_final.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 8 columns):
 #   Column                          Non-Null Count  Dtype
---  ------                          --------------  -----
 0   Air_temp                        10000 non-null  float64
 1   Process_temp                    10000 non-null  float64
 2   Rotational_speed                10000 non-null  float64
 3   Torque                          10000 non-null  float64
 4   Tool_wear                       10000 non-null  int64
 5   Target                          10000 non-null  int64
 6   Type_L                          10000 non-null  uint8
 7   Failure_Type_Random Failures  10000 non-null  uint8
dtypes: float64(4), int64(2), uint8(2)
memory usage: 488.4 KB
```

```
X = df_final.loc[:, df_final.columns!= 'Target']
y = df_final.loc[:, df_final.columns== 'Target']
```

```
X.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 7 columns):
 #   Column                        Non-Null Count  Dtype  
---  ------                        --------------  -----  
 0   Air_temp                      10000 non-null  float64
 1   Process_temp                  10000 non-null  float64
 2   Rotational_speed              10000 non-null  float64
 3   Torque                        10000 non-null  float64
 4   Tool_wear                     10000 non-null  int64  
 5   Type_L                        10000 non-null  uint8  
 6   Failure_Type_Random Failures  10000 non-null  uint8  
dtypes: float64(4), int64(1), uint8(2)
memory usage: 410.3 KB
```

```
y
```

	Target
0	0
1	0
2	0
3	0
4	0
...	...
9995	0
9996	0
9997	0
9998	0
9999	0

10000 rows × 1 columns

```
y.value_counts()
```

```
Target
0         9661
1          339
dtype: int64
```

```
''' Splitting the data into Train & Test (70-30 respectively) '''
```

```
from sklearn.linear_model import LogisticRegression
from sklearn.model_selection import train_test_split



X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state=0)


train = X_train.join(y_train)


train.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 7000 entries, 7681 to 2732
Data columns (total 8 columns):
 #   Column                        Non-Null Count  Dtype  
---  ------                        --------------  -----  
 0   Air_temp                      7000 non-null   float64
 1   Process_temp                  7000 non-null   float64
 2   Rotational_speed              7000 non-null   float64
 3   Torque                        7000 non-null   float64
 4   Tool_wear                     7000 non-null   int64  
 5   Type_L                        7000 non-null   uint8  
 6   Failure_Type_Random Failures  7000 non-null   uint8  
 7   Target                        7000 non-null   int64  
dtypes: float64(4), int64(2), uint8(2)
memory usage: 716.5 KB
```

```
no_failure = train[train.Target == 0]
len(no_failure)
```

```
6760
```

```
yes_failure = train[train.Target == 1]
len(yes_failure)
```

```
240
```

```
from sklearn.utils import resample


# Smote is done - over sampling
yes_failure_os = resample(yes_failure,
                          replace = True,
                          n_samples = len(no_failure),
                          random_state = 14)


train_os = pd.concat([no_failure, yes_failure_os])


train_os.Target.value_counts()
```

```
1    6760
0    6760
```

```
Name: Target, dtype: int64
```

```
X_train_os = train_os.loc[:, train_os.columns != 'Target']
y_train_os = train_os.loc[:, train_os.columns == 'Target']
```

Recurrsive Feature Elimination

```
from sklearn import datasets
from sklearn.feature_selection import RFE
from sklearn.linear_model import LogisticRegression
```

```
logreg = LogisticRegression(max_iter=10000000)
```

```
rfe = RFE(logreg, n_features_to_select=2)
```

```
rfe = rfe.fit(X_train_os, y_train_os.values.ravel())
```

```
rfe.n_features_to_select
```

```
2
```

```
X_train_os.columns[rfe.get_support()]
```

```
Index(['Type_L', 'Failure_Type_Random Failures'], dtype='object')
```

```
cols = X_train_os.columns[rfe.get_support()]
```

```
cols.to_list()
```

```
['Type_L', 'Failure_Type_Random Failures']
```

Logistic Model by statistic apporach

```
#_____________________________________sm model to see p_values
x1 = X_train_os[cols]
```

```
x1.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 13520 entries, 7681 to 4646
Data columns (total 2 columns):
 #   Column                       Non-Null Count  Dtype
---  ------                       --------------  -----
 0   Type_L                       13520 non-null  uint8
 1   Failure_Type_Random Failures  13520 non-null  uint8
```

```
dtypes: uint8(2)
memory usage: 132.0 KB
```

```
y_train_os.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 13520 entries, 7681 to 4646
Data columns (total 1 columns):
 #   Column  Non-Null Count  Dtype
---  ------  --------------  -----
 0   Target  13520 non-null  int64
dtypes: int64(1)
memory usage: 211.2 KB
```

```
y_train_os.value_counts()
```

```
Target
1         6760
0         6760
dtype: int64
```

```
y1 = y_train_os
```

```
y1
```

	Target
7681	0
9031	0
3691	0
202	0
5625	0
...	...
4527	1
3266	1
6540	1
3528	1
4646	1

13520 rows × 1 columns

```
#_____________Stats model
import statsmodels.api as sm
```

```
x1.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 13520 entries, 7681 to 4646
Data columns (total 2 columns):
 #   Column                         Non-Null Count  Dtype
---  ------                         --------------  -----
 0   Type_L                         13520 non-null  uint8
 1   Failure_Type_Random Failures  13520 non-null  uint8
dtypes: uint8(2)
memory usage: 132.0 KB
```

```
y1.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 13520 entries, 7681 to 4646
Data columns (total 1 columns):
 #   Column  Non-Null Count  Dtype
---  ------  --------------  -----
 0   Target  13520 non-null  int64
dtypes: int64(1)
memory usage: 211.2 KB
```

```
logit_model = sm.Logit(y1,x1)
```

```
result = logit_model.fit(method='bfgs')
```

```
Optimization terminated successfully.
         Current function value: 0.165894
         Iterations: 21
         Function evaluations: 22
         Gradient evaluations: 22
```

```
print(result.summary2())
```

```
                            Results: Logit
================================================================================
Model:                  Logit               Pseudo R-squared:     0.761
Dependent Variable:     Target              AIC:                  4489.7701
Date:                   2021-11-29 11:22    BIC:                  4504.7940
No. Observations:       13520               Log-Likelihood:       -2242.9
Df Model:               1                   LL-Null:              -9371.3
Df Residuals:           13518               LLR p-value:          0.0000
Converged:              1.0000              Scale:                1.0000
--------------------------------------------------------------------------------
                             Coef.  Std.Err.    z     P>|z|   [0.025  0.975]
--------------------------------------------------------------------------------
Type_L                       4.2784   0.1269  33.7243 0.0000  4.0297  4.5270
Failure_Type_Random Failures -8.0638   0.1644 -49.0608 0.0000 -8.3859 -7.7416
================================================================================
```

Logistic model by SK learn method

```
from sklearn.linear_model import LogisticRegression
```

```
from sklearn import metrics


logreg= LogisticRegression(solver= 'sag')
logreg.fit(x1, y1)
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/utils/validation.py:985: DataConversic
  y = column_or_1d(y, warn=True)
LogisticRegression(solver='sag')
```

```
## X_test should alsso have only 2 columns
X_test2= X_test[cols]


X_test2.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 3000 entries, 9394 to 5233
Data columns (total 2 columns):
 #   Column                         Non-Null Count  Dtype
---  ------                         --------------  -----
 0   Type_L                         3000 non-null   uint8
 1   Failure_Type_Random Failures  3000 non-null   uint8
dtypes: uint8(2)
memory usage: 29.3 KB
```

```
y_pred= logreg.predict(X_test2)


log_score= logreg.score(X_test2, y_test)


print("Accuracy of logistic regression classifier on test data:{}".format(log_score))
```

```
Accuracy of logistic regression classifier on test data:0.998
```

```
from sklearn.metrics import confusion_matrix


confusion_matrix = confusion_matrix(y_test, y_pred)
print(confusion_matrix)
```

```
[[2901    0]
 [   6   93]]
```

```
from sklearn.metrics import classification_report
print(classification_report(y_test, y_pred))
```

```
                  precision    recall  f1-score   support

               0       1.00      1.00      1.00      2901
               1       1.00      0.94      0.97        99

        accuracy                           1.00      3000
```

```
           macro avg       1.00      0.97      0.98      3000
        weighted avg       1.00      1.00      1.00      3000
```

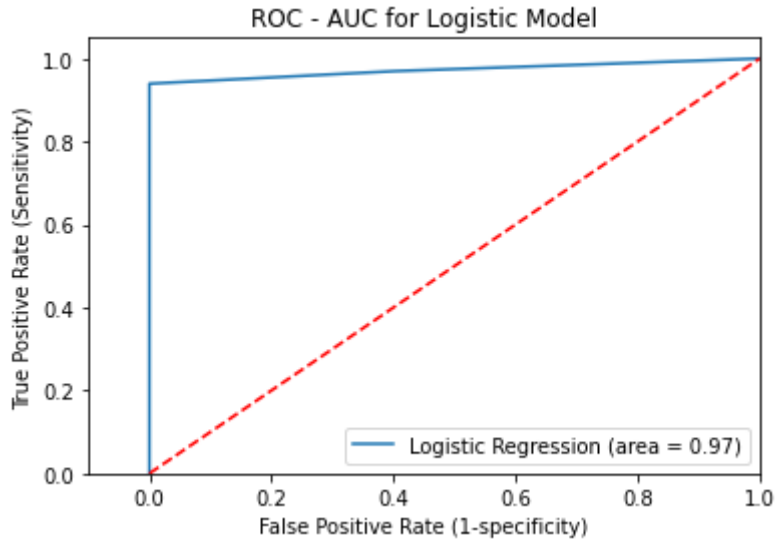
```
from sklearn.metrics import roc_auc_score
from sklearn.metrics import roc_curve


logit_roc_auc = roc_auc_score(y_test, logreg.predict(X_test2))
logit_roc_auc
```

```
0.9696969696969697
```

```
""  Area under curve is 0.96   ""
```

```
fpr, tpr, thresholds = roc_curve(y_test, logreg.predict_proba(X_test2)[:,1])
plt.figure()
plt.plot(fpr, tpr, label='Logistic Regression (area = %0.2f)' % logit_roc_auc)
plt.plot([0, 1], [0, 1],'r--')
plt.xlim([-0.1, 1.0])
plt.ylim([0.0, 1.05])
plt.xlabel('False Positive Rate (1-specificity)')
plt.ylabel('True Positive Rate (Sensitivity)')
plt.title('ROC - AUC for Logistic Model')
plt.legend(loc="lower right")
plt.savefig('Log_ROC')
plt.show()
```



**Decision Tree Model **

```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 8 columns):
 #   Column           Non-Null Count  Dtype
---  ------           --------------  -----
```

```
 0   Type              10000 non-null  object
 1   Air_temp          10000 non-null  float64
 2   Process_temp      10000 non-null  float64
 3   Rotational_speed  10000 non-null  float64
 4   Torque            10000 non-null  float64
 5   Tool_wear         10000 non-null  int64
 6   Target            10000 non-null  int64
 7   Failure_Type      10000 non-null  object
dtypes: float64(4), int64(2), object(2)
memory usage: 625.1+ KB
```

```
df2=df[:]
```

```
df2.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 8 columns):
 #   Column            Non-Null Count  Dtype
---  ------            --------------  -----
 0   Type              10000 non-null  object
 1   Air_temp          10000 non-null  float64
 2   Process_temp      10000 non-null  float64
 3   Rotational_speed  10000 non-null  float64
 4   Torque            10000 non-null  float64
 5   Tool_wear         10000 non-null  int64
 6   Target            10000 non-null  int64
 7   Failure_Type      10000 non-null  object
dtypes: float64(4), int64(2), object(2)
memory usage: 625.1+ KB
```

```
df2.Type.value_counts()
```

```
L    6000
H    4000
Name: Type, dtype: int64
```

```
df2['Type'].replace('L', '1', inplace = True)
df2['Type'].replace('H', '2', inplace = True)
```

```
/usr/local/lib/python3.7/dist-packages/pandas/core/series.py:4582: SettingWithCopyWar
A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/us
  method=method,
```

```
df2.Type.value_counts()
```

```
1    6000
2    4000
Name: Type, dtype: int64
```

```
df2.Failure_Type.value_counts()
```

```
Random Failures             9670
Heat Dissipation Failure     330
Name: Failure_Type, dtype: int64
```

```
df2['Failure_Type'].replace('Random Failures','1',inplace = True)
df2['Failure_Type'].replace('Heat Dissipation Failure','2',inplace = True)
```

```
/usr/local/lib/python3.7/dist-packages/pandas/core/series.py:4582: SettingWithCopyWar
A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/us
  method=method,
```

```
df2.Failure_Type.value_counts()
```

```
1    9670
2     330
Name: Failure_Type, dtype: int64
```

```
from sklearn.preprocessing import LabelEncoder
LE= LabelEncoder()
```

```
df2['Type']= LE.fit_transform(df2['Type'])
df2['Failure_Type']= LE.fit_transform(df2['Failure_Type'])
df2
```

	Type	Air_temp	Process_temp	Rotational_speed	Torque	Tool_wear	Target	Fai
0	1	298.1	308.6	1551.0	42.8	0	0	
1	0	298.2	308.7	1408.0	46.3	3	0	
2	0	298.1	308.5	1498.0	49.4	5	0	
3	0	298.2	308.6	1433.0	39.5	7	0	
4	0	298.2	308.7	1408.0	40.0	9	0	
...	...	...	...	...	...	...	...	...
9995	1	298.8	308.4	1604.0	29.5	14	0	
9996	1	298.9	308.4	1632.0	31.8	17	0	
9997	1	299.0	308.6	1645.0	33.4	22	0	
9998	1	299.0	308.7	1408.0	48.5	25	0	
9999	1	299.0	308.7	1500.0	40.2	30	0	

10000 rows × 8 columns

```
X = df2.loc[:, df2.columns != 'Target']
```

```
y = df2.loc[:, df2.columns == 'Target']
```

```
X.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 7 columns):
 #   Column            Non-Null Count  Dtype  
---  ------            --------------  -----  
 0   Type              10000 non-null  int64  
 1   Air_temp          10000 non-null  float64
 2   Process_temp      10000 non-null  float64
 3   Rotational_speed  10000 non-null  float64
 4   Torque            10000 non-null  float64
 5   Tool_wear         10000 non-null  int64  
 6   Failure_Type      10000 non-null  int64  
dtypes: float64(4), int64(3)
memory usage: 547.0 KB
```

```
y
```

	Target
0	0
1	0
2	0
3	0
4	0
...	...
9995	0
9996	0
9997	0
9998	0
9999	0

10000 rows × 1 columns

```
'''Fit Tree'''
#train test - split

from sklearn.model_selection import train_test_split

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state=0)

from sklearn.tree import DecisionTreeClassifier
```

```
#fit tree on train data
#model
clf = DecisionTreeClassifier()


#Fit Classifier model on train set
clf.fit(X_train, y_train)
```

```
     DecisionTreeClassifier()
```

```
#Predict/estimate_train  X_train
y_pred_train = clf.predict(X_train)


y_pred_train
```

```
     array([0, 0, 0, ..., 0, 0, 0])
```

```
#Predict/estimate_test  X_test
y_pred_test = clf.predict(X_test)


y_pred_test
```

```
     array([0, 0, 0, ..., 0, 0, 0])
```

```
#See the train
from sklearn import tree


tree.plot_tree(clf.fit(X_train, y_train))
```

```
[Text(223.2, 203.85, 'X[6] <= 0.5\ngini = 0.066\nsamples = 7000\nvalue = [6760, 240]
 Text(200.88, 176.67000000000002, 'X[1] <= 303.55\ngini = 0.001\nsamples = 6763\nvalu
 Text(111.6, 149.49, 'X[4] <= 27.35\ngini = 0.001\nsamples = 6432\nvalue = [6430, 2]
 Text(44.64, 122.31, 'X[4] <= 27.25\ngini = 0.003\nsamples = 640\nvalue = [639, 1]'),
 Text(22.32, 95.13, 'gini = 0.0\nsamples = 621\nvalue = [621, 0]'),
 Text(66.96000000000001, 95.13, 'X[5] <= 140.5\ngini = 0.1\nsamples = 19\nvalue = [18
 Text(44.64, 67.94999999999999, 'gini = 0.0\nsamples = 14\nvalue = [14, 0]'),
 Text(89.28, 67.94999999999999, 'X[5] <= 166.5\ngini = 0.32\nsamples = 5\nvalue = [4,
 Text(66.96000000000001, 40.77000000000001, 'gini = 0.0\nsamples = 1\nvalue = [0, 1]
 Text(111.6, 40.77000000000001, 'gini = 0.0\nsamples = 4\nvalue = [4, 0]'),
 Text(178.56, 122.31, 'X[5] <= 20.5\ngini = 0.0\nsamples = 5792\nvalue = [5791, 1]'),
 Text(156.24, 95.13, 'X[5] <= 19.5\ngini = 0.003\nsamples = 623\nvalue = [622, 1]'),
 Text(133.92000000000002, 67.94999999999999, 'gini = 0.0\nsamples = 588\nvalue = [588
 Text(178.56, 67.94999999999999, 'X[4] <= 47.55\ngini = 0.056\nsamples = 35\nvalue =
```

```
#Model has learnt unneccesaary things
#Need to optimize
```

```
from sklearn.metrics import accuracy_score
```

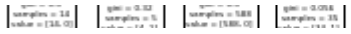
```
print(round(accuracy_score(y_train,y_pred_train), 2))
```

```
1.0
```

```
print(round(accuracy_score(y_test,y_pred_test), 2))
```

```
1.0
```

```
# Accuracy of train data is 1
# Accuracy of test data is 1
```



```
from sklearn import tree
```

```
path = clf.cost_complexity_pruning_path(X_train, y_train)
```

```
path
```

```
{'ccp_alphas': array([0.00000000e+00, 7.14063611e-05, 9.51705829e-05, 6.53636455e-02]
 'impurities': array([0.        , 0.00057125, 0.00085676, 0.06622041])}
```

```
alphas = path['ccp_alphas']
```

```
alphas
```

```
array([0.00000000e+00, 7.14063611e-05, 9.51705829e-05, 6.53636455e-02])
```

```
acrcy_train, acrcy_test = [],[]
```

```
for i in alphas:
    clf = DecisionTreeClassifier(ccp_alpha=i)

    clf.fit(X_train, y_train)
    y_pred_train = clf.predict(X_train)
    y_pred_test = clf.predict(X_test)

    acrcy_train.append(accuracy_score(y_train, y_pred_train))
    acrcy_test.append(accuracy_score(y_test,y_pred_test))

acrcy_train
```

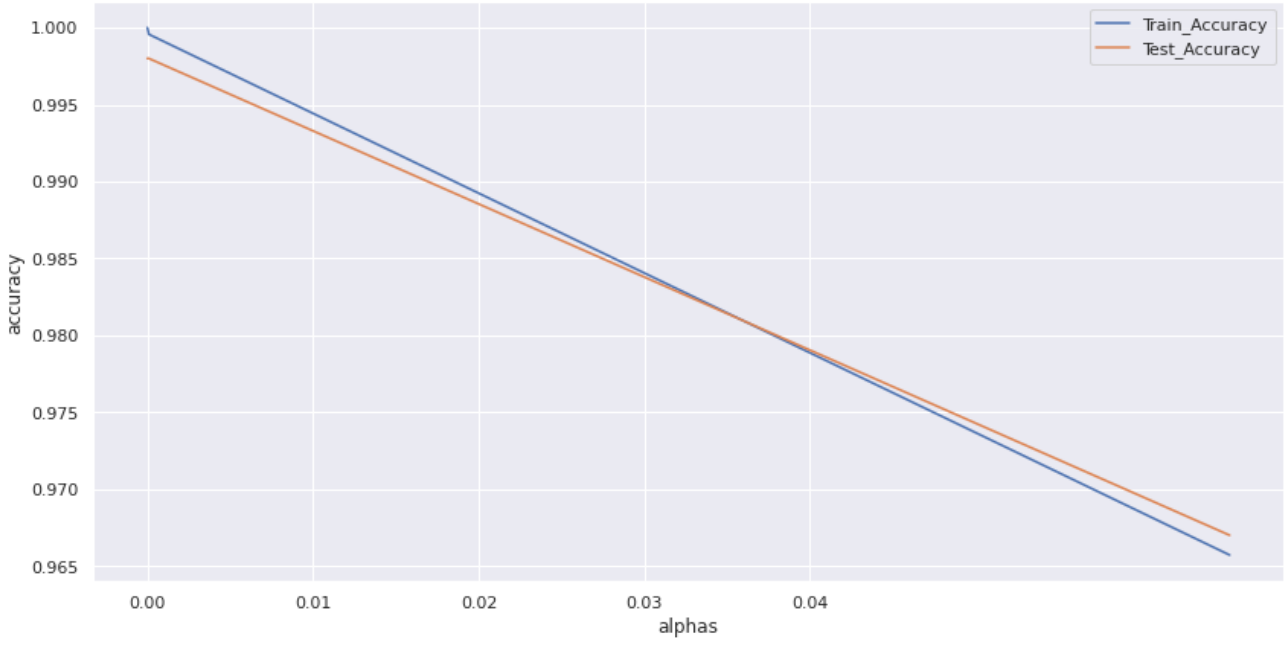
```
[1.0, 0.9997142857142857, 0.9995714285714286, 0.9657142857142857]
```

```
acrcy_test
```

```
[0.998, 0.998, 0.998, 0.967]
```

```
# now we have scores
# lets, plot

sns.set()
plt.figure(figsize = (14,7))
sns.lineplot(y =acrcy_train, x = alphas, label = 'Train_Accuracy')
sns.lineplot(y =acrcy_test, x = alphas, label = 'Test_Accuracy')
plt.xticks(ticks=np.arange(0.00,0.05,0.01))
plt.xlabel('alphas')
plt.ylabel('accuracy')
plt.show()
```



```
#_________with ccp = 0.035
clf = DecisionTreeClassifier(ccp_alpha=0.035, random_state = 14)



clf.fit(X_train,y_train)
```

```
     DecisionTreeClassifier(ccp_alpha=0.035, random_state=14)
```

```
y_pred_train = clf.predict(X_train)


y_pred_test = clf.predict(X_test)


from sklearn.metrics import accuracy_score
print(round(accuracy_score(y_train,y_pred_train), 2))
```

```
     1.0
```

```
print(round(accuracy_score(y_test,y_pred_test), 2))
```

```
     1.0
```

```
### Confusion Matrix
from sklearn.metrics import confusion_matrix
from sklearn.metrics import classification_report


confusion_matrix = confusion_matrix(y_test, y_pred_test)
print(confusion_matrix)
```

```
     [[2901    0]
      [   6   93]]
```

```
### Classification Report
from sklearn.metrics import classification_report


print(classification_report(y_test, y_pred_test))
```

```
                   precision    recall  f1-score   support

                0       1.00      1.00      1.00      2901
                1       1.00      0.94      0.97        99

         accuracy                           1.00      3000
        macro avg       1.00      0.97      0.98      3000
     weighted avg       1.00      1.00      1.00      3000
```

```
############################  ROC AUC Curve

from sklearn.metrics import roc_auc_score
```

```
from sklearn.metrics import roc_curve
from sklearn.metrics import roc_curve, auc, roc_auc_score



predictedProbability = clf.predict_proba(X_test)[:, 1]
fpr,tpr, thresholds = metrics.roc_curve(y_test, predictedProbability)



fpr
```

```
array([0., 0., 1.])
```

```
tpr
```

```
array([0.        , 0.93939394, 1.        ])
```

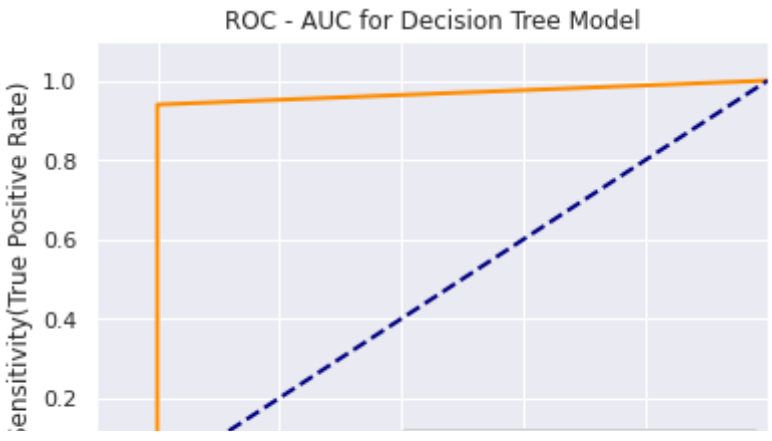
```
thresholds
```

```
array([2.00000000e+00, 1.00000000e+00, 4.43590123e-04])
```

```
dff = pd.DataFrame(dict(fpr = fpr,tpr = tpr))
auc = auc(fpr,tpr)
auc
```

```
0.9696969696969697
```

```
plt.figure()
lw = 2
plt.plot(fpr, tpr, color = 'darkorange',
         lw =lw, label = 'ROC Curve (area = %0.2f)' %auc)
plt.plot([0,1],[0,1], color='navy', lw = lw, linestyle = '--')
plt.xlim([-0.1, 1.0])
plt.ylim([0.0, 1.1])
plt.xlabel('1-Specificity(False Positive Rate)')
plt.ylabel('Sensitivity(True Positive Rate)')
plt.title("ROC - AUC for Decision Tree Model")
plt.legend(loc = "lower right")
plt.show()
```



Random Forest

```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 8 columns):
 #   Column            Non-Null Count  Dtype  
---  ------            --------------  -----  
 0   Type              10000 non-null  object 
 1   Air_temp          10000 non-null  float64
 2   Process_temp      10000 non-null  float64
 3   Rotational_speed  10000 non-null  float64
 4   Torque            10000 non-null  float64
 5   Tool_wear         10000 non-null  int64  
 6   Target            10000 non-null  int64  
 7   Failure_Type      10000 non-null  object 
dtypes: float64(4), int64(2), object(2)
memory usage: 625.1+ KB
```

```
df2=df[:]
```

```
df2.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 8 columns):
 #   Column            Non-Null Count  Dtype  
---  ------            --------------  -----  
 0   Type              10000 non-null  object 
 1   Air_temp          10000 non-null  float64
 2   Process_temp      10000 non-null  float64
 3   Rotational_speed  10000 non-null  float64
 4   Torque            10000 non-null  float64
 5   Tool_wear         10000 non-null  int64  
 6   Target            10000 non-null  int64  
 7   Failure_Type      10000 non-null  object 
dtypes: float64(4), int64(2), object(2)
memory usage: 625.1+ KB
```

```
df2.Type.value_counts()
```

```
1    6000
2    4000
Name: Type, dtype: int64
```

```
df2.Type.value_counts()
```

```
1    6000
2    4000
```

```
Name: Type, dtype: int64
```

```
from sklearn.preprocessing import LabelEncoder
LE= LabelEncoder()
```

```
df2['Type']= LE.fit_transform(df2['Type'])
df2['Failure_Type']= LE.fit_transform(df2['Failure_Type'])
df2
```

	Type	Air_temp	Process_temp	Rotational_speed	Torque	Tool_wear	Target	Fai
0	1	298.1	308.6	1551.0	42.8	0	0	
1	0	298.2	308.7	1408.0	46.3	3	0	
2	0	298.1	308.5	1498.0	49.4	5	0	
3	0	298.2	308.6	1433.0	39.5	7	0	
4	0	298.2	308.7	1408.0	40.0	9	0	
...	...	...	...	...	...	...	...	
9995	1	298.8	308.4	1604.0	29.5	14	0	
9996	1	298.9	308.4	1632.0	31.8	17	0	
9997	1	299.0	308.6	1645.0	33.4	22	0	
9998	1	299.0	308.7	1408.0	48.5	25	0	
9999	1	299.0	308.7	1500.0	40.2	30	0	

10000 rows × 8 columns

```
X = df2.loc[:, df2.columns != 'Target']
y = df2.loc[:, df2.columns == 'Target']
```

```
X.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 7 columns):
 #   Column            Non-Null Count  Dtype  
---  ------            --------------  -----  
 0   Type              10000 non-null  int64  
 1   Air_temp          10000 non-null  float64
 2   Process_temp      10000 non-null  float64
 3   Rotational_speed  10000 non-null  float64
 4   Torque            10000 non-null  float64
 5   Tool_wear         10000 non-null  int64  
 6   Failure_Type      10000 non-null  int64  
dtypes: float64(4), int64(3)
memory usage: 547.0 KB
```

```
y
```

	Target
0	0
1	0
2	0
3	0
4	0
...	...
9995	0
9996	0
9997	0
9998	0
9999	0

10000 rows × 1 columns

```
'''Fit Tree'''
#train test - split

from sklearn.model_selection import train_test_split


X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state=0)



#import the classifier
from sklearn.ensemble import RandomForestClassifier



#Create Classifier object
#in our previous experiment, we found ccp_alphas = 0.013 has the best accuarcy
clf_rf = RandomForestClassifier(n_estimators =100, ccp_alpha= 0.035, random_state = 14)


#fit the classifier with x and y  data = train
mod_rf = clf_rf.fit(X_train, y_train)
```

```
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:2: DataConversionWarning
```

```
#Prediction
y_train_pred = mod_rf.predict(X_train)
y_train_pred
```

```
array([0, 0, 0, ..., 0, 0, 0])
```

```
#Prediction
y_test_pred = mod_rf.predict(X_test)
y_test_pred
```

```
array([0, 0, 0, ..., 0, 0, 0])
```

```
from sklearn.metrics import accuracy_score

print(round(accuracy_score(y_train,y_train_pred), 2))
```

```
0.97
```

```
print(round(accuracy_score(y_test,y_test_pred), 2))
```

```
0.97
```

```
#_________________________________ Extract Feature Importance
fi = pd.DataFrame({'feature': list(X_train.columns),
                   'importance': mod_rf.feature_importances_}).\
    sort_values('importance', ascending = False)
```

```
fi.head()
```

	feature	importance
6	Failure_Type	1.0
0	Type	0.0
1	Air_temp	0.0
2	Process_temp	0.0
3	Rotational_speed	0.0

```
# Accuarcy 2 cells above is 0.97 & 0.97 for Train & test (respectively)
# This accuracy is for having all columns as features in our model
# Lets build a model keeping 1 best features
# that is keeping Failure_Type only
from sklearn.ensemble import RandomForestClassifier

#Create Classifier object
#in our previous experiment Decision Tree model,
#we found ccp_alphas = 0.035 has the best accuarcy
clf_rf1 = RandomForestClassifier(n_estimators =100, ccp_alpha= 0.035, random_state = 14)

# fit the classifier with x and y data=TRAIN,
#this time with Failure_Type only
```

```
X_train.info()
```

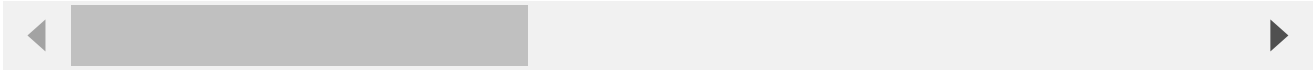
```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 7000 entries, 7681 to 2732
Data columns (total 7 columns):
 #   Column            Non-Null Count  Dtype  
---  ------            --------------  -----  
 0   Type              7000 non-null   int64  
 1   Air_temp          7000 non-null   float64
 2   Process_temp      7000 non-null   float64
 3   Rotational_speed  7000 non-null   float64
 4   Torque            7000 non-null   float64
 5   Tool_wear         7000 non-null   int64  
 6   Failure_Type      7000 non-null   int64  
dtypes: float64(4), int64(3)
memory usage: 437.5 KB
```

```
X_train1 = X_train.iloc[ : ,[6]]
X_train1.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 7000 entries, 7681 to 2732
Data columns (total 1 columns):
 #   Column        Non-Null Count  Dtype
---  ------        --------------  -----
 0   Failure_Type  7000 non-null   int64
dtypes: int64(1)
memory usage: 109.4 KB
```

```
mod_rf1 = clf_rf1.fit(X_train1, y_train)
```

```
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:1: DataConversionWarning
  """Entry point for launching an IPython kernel.
```



```
#Prediction
y_train_pred1 = mod_rf1.predict(X_train1)
y_train_pred1
```

```
array([0, 0, 0, ..., 0, 0, 0])
```

```
X_test.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 3000 entries, 9394 to 5233
Data columns (total 7 columns):
 #   Column            Non-Null Count  Dtype  
---  ------            --------------  -----  
 0   Type              3000 non-null   int64  
 1   Air_temp          3000 non-null   float64
 2   Process_temp      3000 non-null   float64
 3   Rotational_speed  3000 non-null   float64
 4   Torque            3000 non-null   float64
 5   Tool_wear         3000 non-null   int64  
 6   Failure_Type      3000 non-null   int64
```

```
dtypes: float64(4), int64(3)
memory usage: 187.5 KB
```

```
X_test1 = X_test.iloc[ : ,[6]]
X_test1.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 3000 entries, 9394 to 5233
Data columns (total 1 columns):
 #   Column        Non-Null Count  Dtype
---  ------        --------------  -----
 0   Failure_Type  3000 non-null   int64
dtypes: int64(1)
memory usage: 46.9 KB
```

```
#Prediction
y_test_pred1 = mod_rf1.predict(X_test1)
y_test_pred1
```

```
array([0, 0, 0, ..., 0, 0, 0])
```

```
from sklearn.metrics import accuracy_score
```

```
print(round(accuracy_score(y_train,y_train_pred1), 2))
```

```
1.0
```

```
print(round(accuracy_score(y_test,y_test_pred1), 2))
```

```
1.0
```

```
### There is no much difference in accuarcy
#Earlier train accuracy = 1 now with 4 features its 0.97
#Earlier test accuracy = 1 now with 4 features its 0.97
```

```
### Confusion Matrix
from sklearn.metrics import confusion_matrix
```

```
confusion_matrix = confusion_matrix(y_test, y_test_pred1)
print(confusion_matrix)
```

```
[[2901    0]
 [   6   93]]
```

```
### Classification Report
print(classification_report(y_test, y_test_pred1))
```

```
                  precision    recall  f1-score   support
```

```
                  0       1.00      1.00      1.00      2901
                  1       1.00      0.94      0.97        99

           accuracy                           1.00      3000
          macro avg       1.00      0.97      0.98      3000
       weighted avg       1.00      1.00      1.00      3000
```

```
############################  ROC AUC Curve

from sklearn.metrics import roc_auc_score
from sklearn.metrics import roc_curve
from sklearn.metrics import roc_curve, auc, roc_auc_score


predictedProbability1 = mod_rf1.predict_proba(X_test1)[:, 1]
fpr,tpr, thresholds = metrics.roc_curve(y_test, predictedProbability1)


fpr
```

```
     array([0., 0., 1.])
```

```
tpr
```

```
     array([0.        , 0.93939394, 1.        ])
```

```
thresholds
```

```
     array([2.00000000e+00, 1.00000000e+00, 4.31891628e-04])
```

```
dff1 = pd.DataFrame(dict(fpr = fpr,tpr = tpr))
auc1 = auc(fpr,tpr)
auc1
```

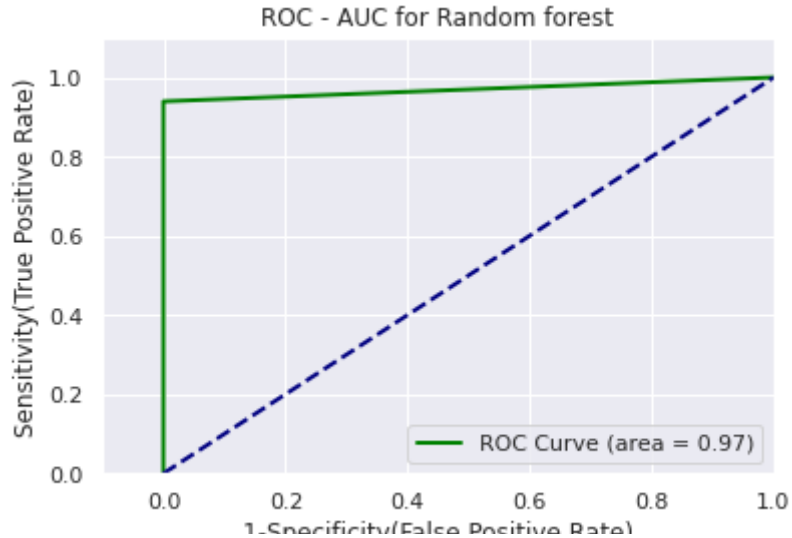
```
     0.9696969696969697
```

```
''' Area Under Curve is 0.96 '''
```

```
     ' Area Under Curve is 0.96 '
```

```
plt.figure()
lw = 2
plt.plot(fpr, tpr, color = 'green',
         lw =lw, label = 'ROC Curve (area = %0.2f)' %auc1)
plt.plot([0,1],[0,1], color='navy', lw = lw, linestyle = '--')
plt.xlim([-0.1, 1.0])
plt.ylim([0.0, 1.1])
plt.xlabel('1-Specificity(False Positive Rate)')
plt.ylabel('Sensitivity(True Positive Rate)')
plt.title("ROC - AUC for Random forest")
```

```
plt.legend(loc = "lower right")
plt.show()
```



Gradient Boosting - Model

```
from sklearn.ensemble import GradientBoostingClassifier
from sklearn.model_selection import GridSearchCV
```

```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 8 columns):
 #   Column            Non-Null Count  Dtype  
---  ------            --------------  -----  
 0   Type              10000 non-null  object 
 1   Air_temp          10000 non-null  float64
 2   Process_temp      10000 non-null  float64
 3   Rotational_speed  10000 non-null  float64
 4   Torque            10000 non-null  float64
 5   Tool_wear         10000 non-null  int64  
 6   Target            10000 non-null  int64  
 7   Failure_Type      10000 non-null  object 
dtypes: float64(4), int64(2), object(2)
memory usage: 625.1+ KB
```

```
X_train1.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 7000 entries, 7681 to 2732
Data columns (total 1 columns):
 #   Column        Non-Null Count  Dtype
---  ------        --------------  -----
 0   Failure_Type  7000 non-null   int64
dtypes: int64(1)
memory usage: 109.4 KB
```

```
GB = GradientBoostingClassifier()
```

```
GB_mod = GB.fit(X_train1, y_train)
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/ensemble/_gb.py:494: DataConversionWar
  y = column_or_1d(y, warn=True)
```

```
# Prediction
y_train_GB = GB_mod.predict(X_train1)
y_train_GB
```

```
array([0, 0, 0, ..., 0, 0, 0])
```

```
X_test1.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 3000 entries, 9394 to 5233
Data columns (total 1 columns):
 #   Column        Non-Null Count  Dtype
---  ------        --------------  -----
 0   Failure_Type  3000 non-null   int64
dtypes: int64(1)
memory usage: 46.9 KB
```

```
# Prediction
y_test_GB = GB_mod.predict(X_test1)
y_test_GB
```

```
array([0, 0, 0, ..., 0, 0, 0])
```

```
print(round(accuracy_score(y_train, y_train_GB), 2))
```

```
1.0
```

```
print(round(accuracy_score(y_test, y_test_GB), 2))
```

```
1.0
```

```
### Confusion Matrix
from sklearn.metrics import confusion_matrix


confusion_matrix = confusion_matrix(y_test, y_test_GB)
print(confusion_matrix)
```

```
[[2901    0]
 [   6   93]]
```

```
### Classification Report
from sklearn.metrics import classification_report
```

```
print(classification_report(y_test, y_test_GB))
```

```
                  precision    recall  f1-score   support

               0       1.00      1.00      1.00      2901
               1       1.00      0.94      0.97        99

        accuracy                           1.00      3000
       macro avg       1.00      0.97      0.98      3000
    weighted avg       1.00      1.00      1.00      3000
```

Knowing your Nearest Neighbours(KNN)

```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 8 columns):
 #   Column            Non-Null Count  Dtype  
---  ------            --------------  -----  
 0   Type              10000 non-null  object 
 1   Air_temp          10000 non-null  float64
 2   Process_temp      10000 non-null  float64
 3   Rotational_speed  10000 non-null  float64
 4   Torque            10000 non-null  float64
 5   Tool_wear         10000 non-null  int64  
 6   Target            10000 non-null  int64  
 7   Failure_Type      10000 non-null  object 
dtypes: float64(4), int64(2), object(2)
memory usage: 625.1+ KB
```

```
df3= df[:]
```

```
df3.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 8 columns):
 #   Column            Non-Null Count  Dtype  
---  ------            --------------  -----  
 0   Type              10000 non-null  object 
 1   Air_temp          10000 non-null  float64
 2   Process_temp      10000 non-null  float64
 3   Rotational_speed  10000 non-null  float64
 4   Torque            10000 non-null  float64
 5   Tool_wear         10000 non-null  int64  
 6   Target            10000 non-null  int64  
 7   Failure_Type      10000 non-null  object 
dtypes: float64(4), int64(2), object(2)
memory usage: 625.1+ KB
```

```
df3.Type.value_counts()
```

```
1    6000
```

```
2    4000
Name: Type, dtype: int64
```

```
df3['Type'].replace('L', '1', inplace = True)
df3['Type'].replace('H', '2', inplace = True)
```

```
/usr/local/lib/python3.7/dist-packages/pandas/core/series.py:4582: SettingWithCopyWar
A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/us
  method=method,
```

```
df3.Type.value_counts()
```

```
1    6000
2    4000
Name: Type, dtype: int64
```

```
df3.Failure_Type.value_counts()
```

```
1    9670
2     330
Name: Failure_Type, dtype: int64
```

```
X = df3.loc[:, df3.columns != 'Target']
y = df3.loc[:, df3.columns == 'Target']
```

```
X.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 7 columns):
 #   Column            Non-Null Count  Dtype  
---  ------            --------------  -----  
 0   Type              10000 non-null  object 
 1   Air_temp          10000 non-null  float64
 2   Process_temp      10000 non-null  float64
 3   Rotational_speed  10000 non-null  float64
 4   Torque            10000 non-null  float64
 5   Tool_wear         10000 non-null  int64  
 6   Failure_Type      10000 non-null  object 
dtypes: float64(4), int64(1), object(2)
memory usage: 547.0+ KB
```

```
y
```

	Target
0	0
1	0
2	0
3	0
4	0
...	...
9995	0
9996	0
9997	0

```
from sklearn.linear_model import LogisticRegression
from sklearn.model_selection import train_test_split


X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state=0)


from sklearn.neighbors import KNeighborsClassifier


#Building Model @ n_neighbors = 4

knn = KNeighborsClassifier(n_neighbors = 4)
print(knn)
mpm_knn = knn.fit(X_train, y_train)
print(mpm_knn)
```

```
KNeighborsClassifier(n_neighbors=4)
KNeighborsClassifier(n_neighbors=4)
/usr/local/lib/python3.7/dist-packages/sklearn/neighbors/_classification.py:198: Data
  return self._fit(X, y)
```

```
#Applying on Test data for prediction
y_pred_KNN = mpm_knn.predict(X_test)
print(y_pred_KNN)
```

```
[0 0 0 ... 0 0 0]
```

```
#Prediction Score
mpm_knn.score(X_test, y_test)
```

```
0.9683333333333334
```

```
#Accuracy Score
from sklearn.metrics import accuracy_score
```

```
accuracy_score(y_test, y_pred_KNN)
```

```
0.9683333333333334
```

```
# creating a confusion matrix
from sklearn.metrics import confusion_matrix
knn_predictions = knn.predict(X_test)
cm = confusion_matrix(y_test, knn_predictions)
cm
```

```
array([[2893,    8],
       [  87,   12]])
```

```
### Classification Report
from sklearn.metrics import classification_report
print(classification_report(y_test, knn_predictions))
```

```
                precision    recall  f1-score   support

             0       0.97      1.00      0.98      2901
             1       0.60      0.12      0.20        99

      accuracy                           0.97      3000
     macro avg       0.79      0.56      0.59      3000
  weighted avg       0.96      0.97      0.96      3000
```

SVM

```
df3.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 8 columns):
 #   Column            Non-Null Count  Dtype  
---  ------            --------------  -----  
 0   Type              10000 non-null  object 
 1   Air_temp          10000 non-null  float64
 2   Process_temp      10000 non-null  float64
 3   Rotational_speed  10000 non-null  float64
 4   Torque            10000 non-null  float64
 5   Tool_wear         10000 non-null  int64  
 6   Target            10000 non-null  int64  
 7   Failure_Type      10000 non-null  object 
dtypes: float64(4), int64(2), object(2)
memory usage: 625.1+ KB
```

```
df3.Type.value_counts()
```

```
1    6000
2    4000
Name: Type, dtype: int64
```

```
X = df3.loc[:, df3.columns != 'Target']
y = df3.loc[:, df3.columns == 'Target']
```

```
X.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 7 columns):
 #   Column            Non-Null Count  Dtype  
---  ------            --------------  -----  
 0   Type              10000 non-null  object 
 1   Air_temp          10000 non-null  float64
 2   Process_temp      10000 non-null  float64
 3   Rotational_speed  10000 non-null  float64
 4   Torque            10000 non-null  float64
 5   Tool_wear         10000 non-null  int64  
 6   Failure_Type      10000 non-null  object 
dtypes: float64(4), int64(1), object(2)
memory usage: 547.0+ KB
```

```
y
```

	Target
0	0
1	0
2	0
3	0
4	0
...	...
9995	0
9996	0
9997	0
9998	0
9999	0

10000 rows × 1 columns

```
# splitting
from sklearn.linear_model import LogisticRegression
from sklearn.model_selection import train_test_split
```

```
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state=0)
```

```
from sklearn import svm
from sklearn.svm import SVC
```

```
svm_model= svm.SVC(kernel='linear', C=1, gamma='auto', probability= True).fit(X_train, y_t
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/utils/validation.py:985: DataConversic
  y = column_or_1d(y, warn=True)
```

```
y_pred_SVM = svm_model.predict(X_test)
```

```
# model accuracy for X_test
accuracy = svm_model.score(X_test, y_test)
print(accuracy)
```

```
0.998
```

```
# creating a confusion matrix
from sklearn.metrics import confusion_matrix
cm = confusion_matrix(y_test, y_pred_SVM)
cm
```

```
array([[2901,    0],
       [   6,   93]])
```

```
### Classification Report
from sklearn.metrics import classification_report
print(classification_report(y_test, y_pred_SVM))
```

```
                  precision    recall  f1-score   support

               0       1.00      1.00      1.00      2901
               1       1.00      0.94      0.97        99

        accuracy                           1.00      3000
       macro avg       1.00      0.97      0.98      3000
    weighted avg       1.00      1.00      1.00      3000
```

Naive Bayes

```
from sklearn.naive_bayes import GaussianNB
gnb = GaussianNB().fit(X_train, y_train)
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/utils/validation.py:985: DataConversic
  y = column_or_1d(y, warn=True)
```

```
gnb_predictions = gnb.predict(X_test)
```

```
# accuracy on X_test
accuracy = gnb.score(X_test, y_test)
print(accuracy)
```

```
0.998
```

```
# creating a confusion matrix
cm = confusion_matrix(y_test, gnb_predictions)
cm
```

```
array([[2901,    0],
       [   6,   93]])
```

```
### Classification Report
from sklearn.metrics import classification_report
print(classification_report(y_test, gnb_predictions))
```

```
                  precision    recall  f1-score   support

               0       1.00      1.00      1.00      2901
               1       1.00      0.94      0.97        99

        accuracy                           1.00      3000
       macro avg       1.00      0.97      0.98      3000
    weighted avg       1.00      1.00      1.00      3000
```