In [3]:
```python
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
import seaborn as sns
```

In [28]:
```python
import os
import pandas as pd
import numpy as np
import seaborn as sns
import matplotlib.pyplot as plt
from matplotlib import rc, rcParams
import datetime as dt
import warnings
warnings.filterwarnings("ignore")
import math
import random
import itertools

from sklearn.preprocessing import MinMaxScaler, RobustScaler, Stand
from sklearn.metrics import classification_report, roc_auc_score, c
from sklearn.model_selection import train_test_split, GridSearchCV,
from sklearn.linear_model import LogisticRegression
from sklearn.svm import SVC
from sklearn.neighbors import KNeighborsClassifier, LocalOutlierFac
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import RandomForestClassifier, GradientBoosti

from xgboost import XGBRFClassifier
from lightgbm import LGBMClassifier
from catboost import CatBoostClassifier
from imblearn.ensemble import BalancedBaggingClassifier
from imblearn.over_sampling import SMOTE
from sklearn.metrics import balanced_accuracy_score
from imblearn.ensemble import BalancedRandomForestClassifier
```

In [30]:
```python
df = pd.read_csv("/Users/nimishvadgaonkar/Downloads/train.csv")
```

EDA

In [34]:
```python
df.isna().sum()
```

```
Out[34]:  AccountAge                  0
          MonthlyCharges              0
          TotalCharges                0
          SubscriptionType            0
          PaymentMethod               0
          PaperlessBilling            0
          ContentType                 0
          MultiDeviceAccess           0
          DeviceRegistered            0
          ViewingHoursPerWeek         0
          AverageViewingDuration      0
          ContentDownloadsPerMonth    0
          GenrePreference             0
          UserRating                  0
          SupportTicketsPerMonth      0
          Gender                      0
          WatchlistSize               0
          ParentalControl             0
          SubtitlesEnabled            0
          CustomerID                  0
          Churn                       0
          dtype: int64
```

In [36]: `df.duplicated().sum()`

Out[36]: 0

In [40]: `df.nunique()`

```
Out[40]:  AccountAge                     119
          MonthlyCharges              243787
          TotalCharges                243787
          SubscriptionType                 3
          PaymentMethod                    4
          PaperlessBilling                 2
          ContentType                      3
          MultiDeviceAccess                2
          DeviceRegistered                 4
          ViewingHoursPerWeek         243787
          AverageViewingDuration      243787
          ContentDownloadsPerMonth        50
          GenrePreference                  5
          UserRating                  243787
          SupportTicketsPerMonth          10
          Gender                           2
          WatchlistSize                   25
          ParentalControl                  2
          SubtitlesEnabled                 2
          CustomerID                  243787
          Churn                            2
          dtype: int64
```

In [42]: `df.info()`

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 243787 entries, 0 to 243786
Data columns (total 21 columns):
 #   Column                   Non-Null Count   Dtype
---  ------                   --------------   -----
 0   AccountAge               243787 non-null  int64
 1   MonthlyCharges           243787 non-null  float64
 2   TotalCharges             243787 non-null  float64
 3   SubscriptionType         243787 non-null  object
 4   PaymentMethod            243787 non-null  object
 5   PaperlessBilling         243787 non-null  object
 6   ContentType              243787 non-null  object
 7   MultiDeviceAccess        243787 non-null  object
 8   DeviceRegistered         243787 non-null  object
 9   ViewingHoursPerWeek      243787 non-null  float64
 10  AverageViewingDuration   243787 non-null  float64
 11  ContentDownloadsPerMonth 243787 non-null  int64
 12  GenrePreference          243787 non-null  object
 13  UserRating               243787 non-null  float64
 14  SupportTicketsPerMonth   243787 non-null  int64
 15  Gender                   243787 non-null  object
 16  WatchlistSize            243787 non-null  int64
 17  ParentalControl          243787 non-null  object
 18  SubtitlesEnabled         243787 non-null  object
 19  CustomerID               243787 non-null  object
 20  Churn                    243787 non-null  int64
dtypes: float64(5), int64(5), object(11)
memory usage: 39.1+ MB
```

In [44]: `df.columns`

Out[44]: Index(['AccountAge', 'MonthlyCharges', 'TotalCharges', 'Subscripti
          onType', 'PaymentMethod', 'PaperlessBilling', 'ContentType', 'Mult
          iDeviceAccess', 'DeviceRegistered', 'ViewingHoursPerWeek', 'Averag
          eViewingDuration', 'ContentDownloadsPerMonth', 'GenrePreference',
          'UserRating', 'SupportTicketsPerMonth', 'Gender', 'WatchlistSize',
          'ParentalControl', 'SubtitlesEnabled', 'CustomerID', 'Churn'], dty
          pe='object')

In [52]: `df.describe()`

Out[52]:

	AccountAge	MonthlyCharges	TotalCharges	ViewingHoursPerWe
count	243787.000000	243787.000000	243787.000000	243787.00000
mean	60.083758	12.490695	750.741017	20.5021
std	34.285143	4.327615	523.073273	11.2437!
min	1.000000	4.990062	4.991154	1.00000
25%	30.000000	8.738543	329.147027	10.7639!
50%	60.000000	12.495555	649.878487	20.5231
75%	90.000000	16.238160	1089.317362	30.2193!
max	119.000000	19.989957	2378.723844	39.9997:

In [16]:
```python
df.columns
```

Out[16]: Index(['AccountAge', 'MonthlyCharges', 'TotalCharges', 'Subscripti
onType',
        'PaymentMethod', 'PaperlessBilling', 'ContentType', 'MultiD
eviceAccess',
        'DeviceRegistered', 'ViewingHoursPerWeek', 'AverageViewingD
uration',
        'ContentDownloadsPerMonth', 'GenrePreference', 'UserRatin
g',
        'SupportTicketsPerMonth', 'Gender', 'WatchlistSize', 'Paren
talControl',
        'SubtitlesEnabled', 'CustomerID', 'Churn'],
       dtype='object')

In [20]:
```python
df.head(20)
```

Out[20]:

	AccountAge	MonthlyCharges	TotalCharges	SubscriptionType	PaymentI
0	20	11.055215	221.104302	Premium	Maile
1	57	5.175208	294.986882	Basic	Cre
2	73	12.106657	883.785952	Basic	Maile
3	32	7.263743	232.439774	Basic	Electroni
4	57	16.953078	966.325422	Premium	Electroni
5	113	7.295744	824.419081	Premium	Maile
6	38	12.340675	468.945639	Premium	Bank
7	25	7.247550	181.188753	Standard	Electroni
8	26	19.803233	514.884050	Standard	Bank
9	14	18.842934	263.801080	Standard	Bank
10	114	18.323630	2088.893783	Premium	Maile
11	3	16.271635	48.814904	Standard	Electroni
12	64	7.749444	495.964395	Basic	Maile
13	43	6.209336	267.001469	Premium	Bank
14	98	7.589784	743.798786	Basic	Electroni
15	47	16.692975	784.569833	Standard	Electroni
16	11	14.665402	161.319419	Basic	Maile
17	50	14.666920	733.345994	Standard	Electroni
18	5	5.973690	29.868449	Premium	Bank
19	63	5.129317	323.146996	Standard	Cre

20 rows × 21 columns

VISUALIZATIONS

In [99]:
```python
# Grab Variables
def grab_variable(dataframe, num_th=10, car_th=20, var_name=False):

    # Categoric Variables #

    cat_var = [i for i in dataframe.columns if dataframe[i].dtypes

    num_but_cat = [i for i in dataframe.columns if dataframe[i].dty
                    and dataframe[i].nunique() <= num_th]

    cat_but_car = [i for i in dataframe.columns if dataframe[i].dty
                    and dataframe[i].nunique() > car_th]

    cat_var = cat_var + num_but_cat
```

```python
        cat_var = [i for i in cat_var if i not in cat_but_car]

        # Numeric Variables #
        num_var = [i for i in dataframe.columns if dataframe[i].dtypes
                   and dataframe[i].nunique() > num_th]

        print("Observation:", len(dataframe))
        print("Number of Variables:", len(dataframe.columns))
        print("Number of Categoric Variables:", len(cat_var))
        print("Number of Num but Cat Variables:", len(num_but_cat))
        print("Number of Cat but Cardinal Variables:", len(cat_but_car)
        print("Number of Numeric Variables:", len(num_var))

        if var_name:
            print("Categoric Variables:", cat_var)
            print("Numeric But Categoric Variables:", num_but_cat)
            print("Categoric But Cardinal Variables:", cat_but_car)
            print("Numeric Variables:", num_var)
        return cat_var, cat_but_car, num_var

cat_var, cat_but_car, num_var = grab_variable(df)
```

```
Observation: 243787
Number of Variables: 26
Number of Categoric Variables: 17
Number of Num but Cat Variables: 5
Number of Cat but Cardinal Variables: 1
Number of Numeric Variables: 8
```

In [25]:
```python
df.plot(kind="box", subplots=True, figsize=(15, 30), layout=(7, 3))
plt.title("Boxplot")
plt.show()
```
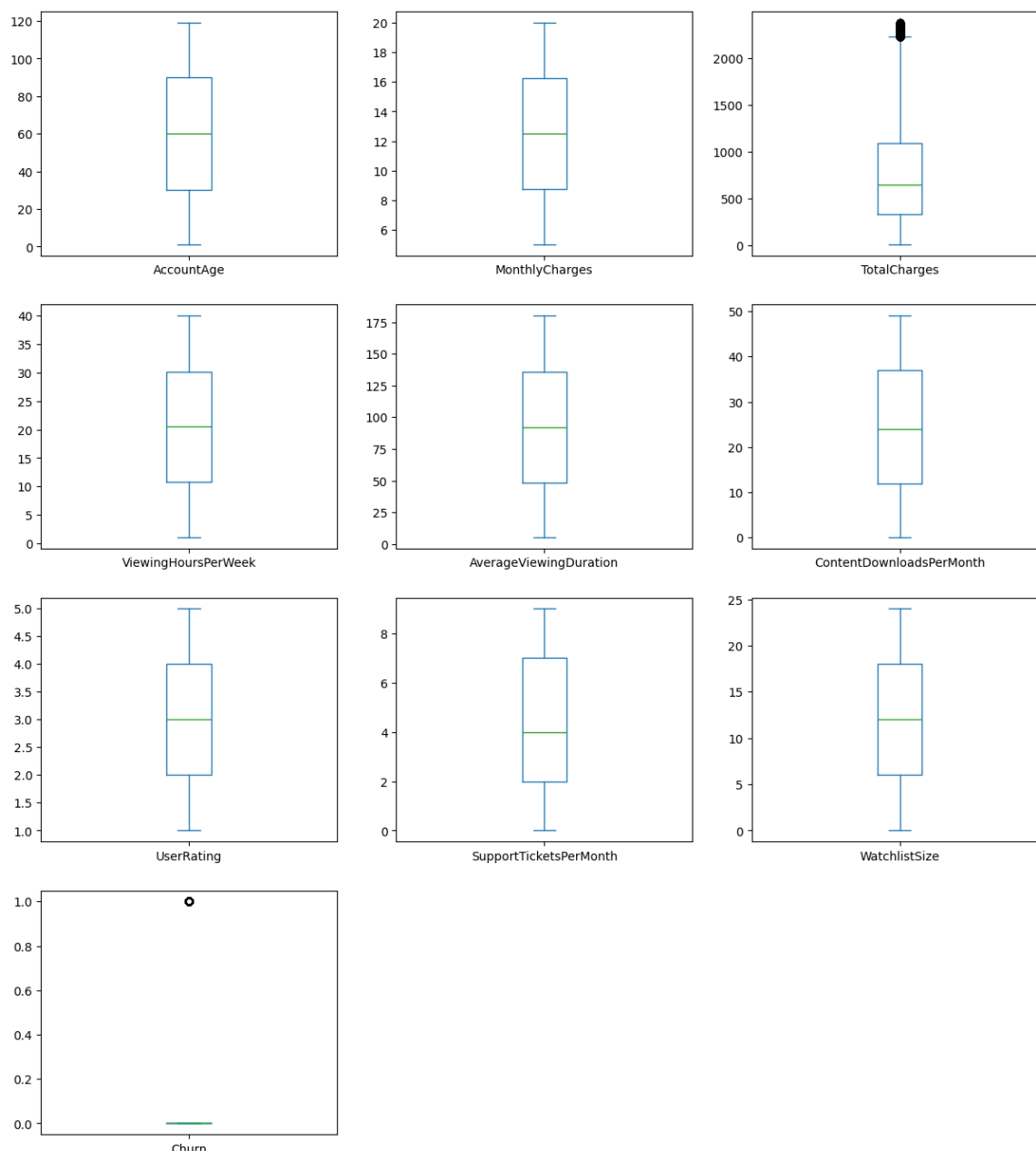
In [73]:
```python
def outlier_thresholds(df, variable, q1=0.25, q3=0.75):
    q1 = df[variable].quantile(q1)
    q3 = df[variable].quantile(q3)
    iqr = q3 - q1
    lower_limit = q1 - 1.5 * iqr
    upper_limit = q3 + 1.5 * iqr
    return lower_limit, upper_limit

for i in num_var:
    print(i, ":", outlier_thresholds(df, i))
```

```
AccountAge : (-60.0, 180.0)
MonthlyCharges : (-2.5108822537315287, 27.487585566502734)
TotalCharges : (-811.1084761822483, 2229.5728643148022)
ViewingHoursPerWeek : (-18.419212297484723, 59.40256110709355)
AverageViewingDuration : (-82.90608528289064, 267.1965276075546)
ContentDownloadsPerMonth : (-25.5, 74.5)
UserRating : (-1.0011033867446884, 7.004113639054296)
WatchlistSize : (-12.0, 36.0)
```

In [75]:
```python
def check_outlier(df, variable):
    lower_limit, upper_limit = outlier_thresholds(df, variable)
    if df[(df[variable] < lower_limit) | (df[variable] > upper_limi
        print(variable, "-->", len(df[(df[variable] < lower_limit)
        return True
    else:
        return False


for i in num_var:
    print(i, ":", check_outlier(df, i))
```

```
AccountAge : False
MonthlyCharges : False
TotalCharges --> 741
TotalCharges : True
ViewingHoursPerWeek : False
AverageViewingDuration : False
ContentDownloadsPerMonth : False
UserRating : False
WatchlistSize : False
```

In [79]:
```python
def suppress_outliers(df, variable):
    lower_limit, upper_limit = outlier_thresholds(df, variable)
    df.loc[df[variable] < lower_limit, variable] = lower_limit
    df.loc[df[variable] > upper_limit, variable] = upper_limit

for i in num_var:
    if check_outlier(df, i) == True:
        suppress_outliers(df, i)
        print("Suppressed Outliers for " + i)
    else:
        continue
```

```
TotalCharges --> 741
Suppressed Outliers for TotalCharges
```

In [81]:
```python
for i in num_var:
    print(i, ":", check_outlier(df, i))
```

```
AccountAge : False
MonthlyCharges : False
TotalCharges : False
ViewingHoursPerWeek : False
AverageViewingDuration : False
ContentDownloadsPerMonth : False
UserRating : False
WatchlistSize : False
```

In [83]:
```python
def pearson_corr(dataframe, num_cols, plot=False):

    print(df[num_cols].corr())

    if plot:
        plt.figure(figsize=[10, 8])
        sns.heatmap(data=dataframe[num_cols].corr(), annot=True, fm
                    linecolor="pink", cmap="rainbow")
        plt.xticks(rotation=45, fontsize=12)
```
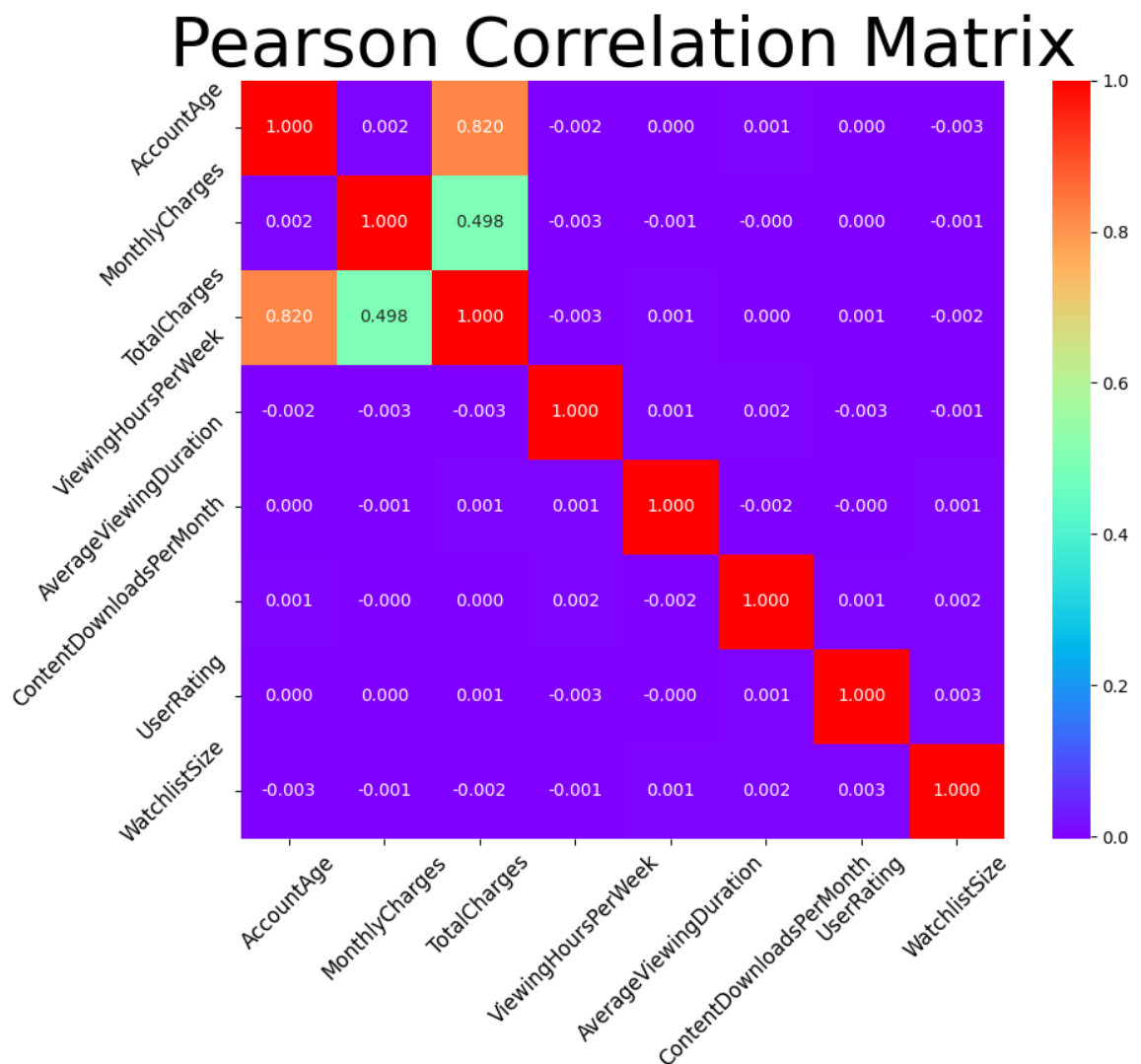
```python
        plt.yticks(rotation=45, fontsize=12)
        plt.title("Pearson Correlation Matrix", fontsize=40)
        print(plt.show())

pearson_corr(df, num_var, plot=True)
```

```
                            AccountAge  MonthlyCharges  TotalCharges
ViewingHoursPerWeek  AverageViewingDuration  ContentDownloadsPerMont
h  UserRating  WatchlistSize
AccountAge                    1.000000        0.001706      0.820367
-0.001640              0.000191                 0.001220    0.000
440      -0.002640
MonthlyCharges                0.001706        1.000000      0.498142
-0.003029             -0.000604                -0.000127    0.000
056      -0.000540
TotalCharges                  0.820367        0.498142      1.000000
-0.003004              0.000848                 0.000205    0.000
596      -0.001778
ViewingHoursPerWeek          -0.001640       -0.003029     -0.003004
1.000000              0.000949                 0.002149   -0.0031
85      -0.000750
AverageViewingDuration        0.000191       -0.000604      0.000848
0.000949              1.000000                -0.002397   -0.0004
06       0.000749
ContentDownloadsPerMonth      0.001220       -0.000127      0.000205
0.002149             -0.002397                 1.000000    0.0012
94       0.002324
UserRating                    0.000440        0.000056      0.000596
-0.003185             -0.000406                 0.001294    1.000
000       0.002567
WatchlistSize                -0.002640       -0.000540     -0.001778
-0.000750              0.000749                 0.002324    0.002
567       1.000000
```

Pearson Correlation Matrix

	AccountAge	MonthlyCharges	TotalCharges	ViewingHoursPerWeek	AverageViewingDuration	ContentDownloadsPerMonth	UserRating	WatchlistSize
AccountAge	1.000	0.002	0.820	-0.002	0.000	0.001	0.000	-0.003
MonthlyCharges	0.002	1.000	0.498	-0.003	-0.001	-0.000	0.000	-0.001
TotalCharges	0.820	0.498	1.000	-0.003	0.001	0.000	0.001	-0.002
ViewingHoursPerWeek	-0.002	-0.003	-0.003	1.000	0.001	0.002	-0.003	-0.001
AverageViewingDuration	0.000	-0.001	0.001	0.001	1.000	-0.002	-0.000	0.001
ContentDownloadsPerMonth	0.001	-0.000	0.000	0.002	-0.002	1.000	0.001	0.002
UserRating	0.000	0.000	0.001	-0.003	-0.000	0.001	1.000	0.003
WatchlistSize	-0.003	-0.001	-0.002	-0.001	0.001	0.002	0.003	1.000

None

FEATURE ENGINEERING

```
In [85]: print(df["AccountAge"].describe().T)

labels = ["new_customer", "standard_customer", "old_customer"]

bins = [df["AccountAge"].min() - 1,
        24, 60,
        df["AccountAge"].max() + 1]

df["AccountAge_Segment"] = pd.cut(x=df["AccountAge"], bins=bins, la

print(df.groupby("AccountAge_Segment").agg({"ViewingHoursPerWeek":
                                            "AverageViewingDuration"
                                            "ContentDownloadsPerMont
```

```
count     243787.000000
mean          60.083758
std           34.285143
min            1.000000
25%           30.000000
50%           60.000000
75%           90.000000
max          119.000000
Name: AccountAge, dtype: float64
```

```
                     ViewingHoursPerWeek AverageViewingDuration Conten
tDownloadsPerMonth
                                    mean                   mean

mean     count
AccountAge_Segment
new_customer                   20.507195              92.483013
24.548743   48786
standard_customer              20.532669              92.123164
24.480652   73856
old_customer                   20.481571              92.261785
24.499236  121145
```

In [87]:
```python
import nltk
from collections import Counter
from sklearn.feature_extraction.text import CountVectorizer
df["ViewingHoursPerWeek_Segment"] = pd.qcut(df["ViewingHoursPerWeek
text_cols = df.select_dtypes(include=["object"]).columns.tolist()
if text_cols:
    vectorizer = CountVectorizer()
    bow_matrix = vectorizer.fit_transform(df[text_cols[0]])
    bow_df = pd.DataFrame(bow_matrix.toarray(), columns=vectorizer.
    df = pd.concat([df, bow_df], axis=1)
agg_df = df.groupby("ViewingHoursPerWeek_Segment").agg({
    "ViewingHoursPerWeek": "mean",
    "AverageViewingDuration": "mean",
    "ContentDownloadsPerMonth": ["mean", "count"]
})
print(agg_df)
agg_df["ViewingHoursPerWeek"]["mean"].plot(kind="bar", color=["red"
plt.xlabel("Viewing Hours Per Week Segment")
plt.ylabel("Average Viewing Hours Per Week")
plt.title("Average Viewing Hours Per Week by Segment", fontsize=16)
plt.xticks(rotation=45)
plt.grid(axis="y", linestyle="--", alpha=0.7)
plt.show()
```

```
                     ViewingHoursPerWeek AverageViewingDurati
on ContentDownloadsPerMonth
                                    mean                   me
an                   mean  count
ViewingHoursPerWeek_Segment
less_watcher                    7.517136              92.1122
39               24.504159  81262
watcher                        20.511331              92.5024
99               24.460154  81262
hard_watcher                   33.477910              92.1774
47               24.546226  81263
```

Average Viewing Hours Per Week by Segment
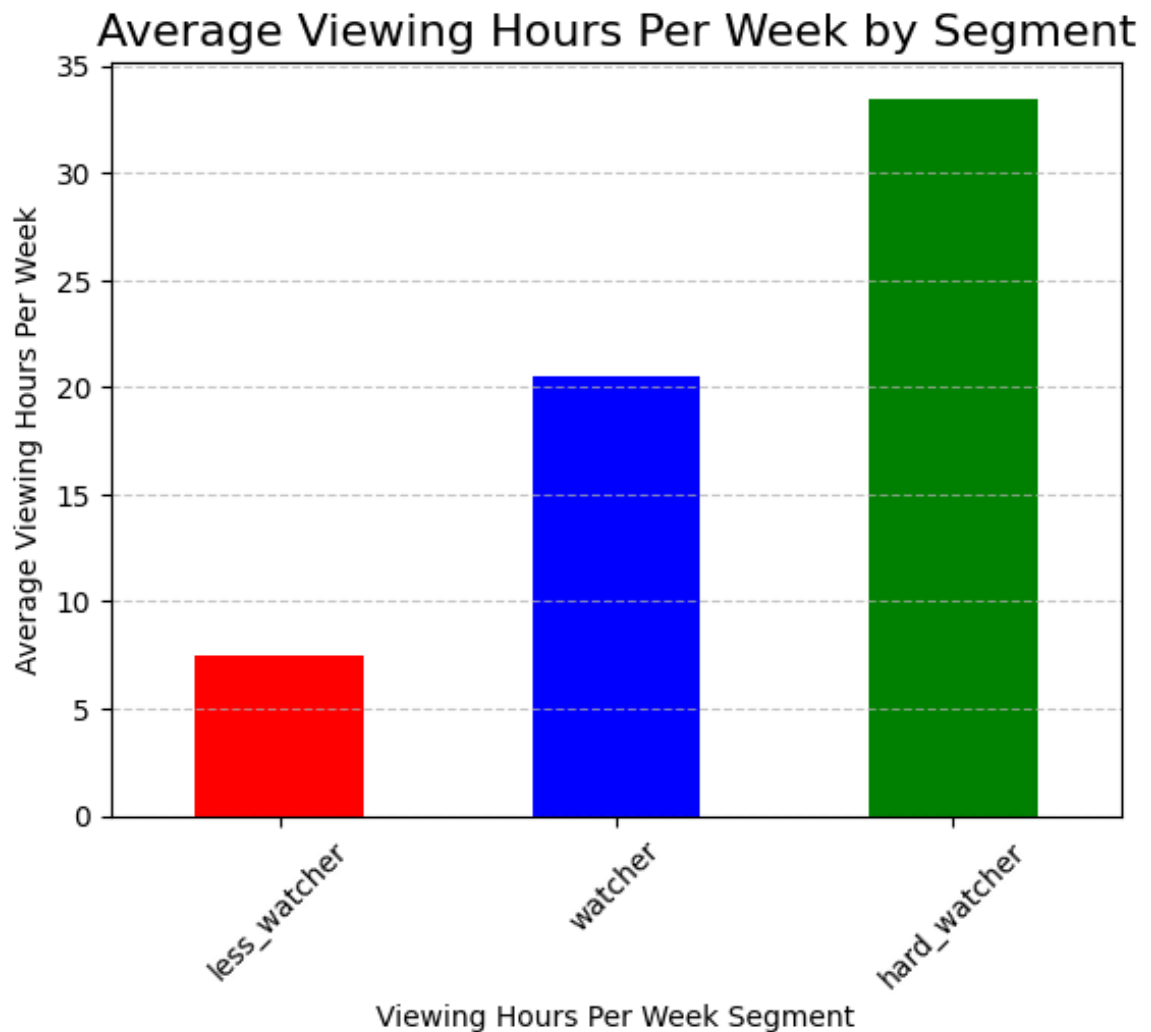
In [89]:
```python
unique_tickets = df["SupportTicketsPerMonth"].nunique()
ticket_counts = df["SupportTicketsPerMonth"].value_counts()

print(f"Number of Unique --> {unique_tickets}")
print("Value Counts:\n", ticket_counts)
agg_result = df.groupby("SupportTicketsPerMonth").agg(
    MonthlyCharges_mean=("MonthlyCharges", "mean"),
    ViewingHoursPerWeek_mean=("ViewingHoursPerWeek", "mean"),
    Churn_mean=("Churn", "mean"),
    Churn_count=("Churn", "count"),
)
print(agg_result)
df["New_SupportTicketsPerMonth"] = df["SupportTicketsPerMonth"].app
    lambda x: 0 if 0 <= x < 6 else 1
)
df.head()
```

```
Number of Unique --> 10
Value Counts:
 SupportTicketsPerMonth
7    24626
4    24618
2    24477
9    24435
8    24400
3    24360
6    24296
0    24292
1    24283
5    24000
Name: count, dtype: int64
```

SupportTicketsPerMonth	Churn_mean	Churn_count	MonthlyCharges_mean	ViewingHoursPerWeek_mean
0	0.133583	24292	12.470947	20.63253
1	0.145081	24283	12.452410	20.43360
2	0.152020	24477	12.490431	20.42132
3	0.161289	24360	12.509898	20.36984
4	0.174547	24618	12.535406	20.63089
5	0.182750	24000	12.510057	20.38870
6	0.196041	24296	12.530725	20.63621
7	0.206164	24626	12.484640	20.45861
8	0.224385	24400	12.441412	20.47084
9	0.235973	24435	12.480939	20.57735

Out[89]:

	AccountAge	MonthlyCharges	TotalCharges	SubscriptionType	PaymentM
0	20	11.055215	221.104302	Premium	Mailed
1	57	5.175208	294.986882	Basic	Cred
2	73	12.106657	883.785952	Basic	Mailed
3	32	7.263743	232.439774	Basic	Electronic
4	57	16.953078	966.325422	Premium	Electronic

In [91]:
```python
df.drop("SupportTicketsPerMonth", axis=1, inplace=True)
```

In [107…
```python
from sklearn.preprocessing import OneHotEncoder
cat_var, cat_but_car, num_var = grab_variable(df)
cat_var.remove("Churn")
encoder = OneHotEncoder(drop='first', dtype=int, sparse_output=Fals
encoded_features = encoder.fit_transform(df[cat_var])
```

```python
encoded_df = pd.DataFrame(encoded_features, columns=encoder.get_fea
df = df.drop(columns=cat_var).reset_index(drop=True)
df = pd.concat([df, encoded_df], axis=1)
```

```
Observation: 243787
Number of Variables: 37
Number of Categoric Variables: 28
Number of Num but Cat Variables: 28
Number of Cat but Cardinal Variables: 1
Number of Numeric Variables: 8
```

In [109…
```python
from sklearn.preprocessing import StandardScaler, MinMaxScaler, Rob

def standardize_data(dataframe, variable, method="standard"):
    scalers = {
        "standard": StandardScaler(),
        "minmax": MinMaxScaler(),
        "robust": RobustScaler(),
    }

    if method in scalers:
        scaler = scalers[method]
        dataframe[variable] = scaler.fit_transform(dataframe[variab
    else:
        raise ValueError("Invalid method. Choose from 'standard', '


standardize_data(df, num_var, method="standard")
```

In [42]:
```python
from sklearn.preprocessing import LabelEncoder

for col in categorical_columns:
    encoder_name = f"{col}_encoder"
    print(f"\n{encoder_name} = LabelEncoder()")
    print(f"train_data['{col}'] = {encoder_name}.fit_transform(trai
```

```
SubscriptionType_encoder = LabelEncoder()
train_data['SubscriptionType'] = SubscriptionType_encoder.fit_transf
orm(train_data['SubscriptionType'])

PaymentMethod_encoder = LabelEncoder()
train_data['PaymentMethod'] = PaymentMethod_encoder.fit_transform(tr
ain_data['PaymentMethod'])

PaperlessBilling_encoder = LabelEncoder()
train_data['PaperlessBilling'] = PaperlessBilling_encoder.fit_transf
orm(train_data['PaperlessBilling'])

ContentType_encoder = LabelEncoder()
train_data['ContentType'] = ContentType_encoder.fit_transform(train_
data['ContentType'])

MultiDeviceAccess_encoder = LabelEncoder()
train_data['MultiDeviceAccess'] = MultiDeviceAccess_encoder.fit_tran
sform(train_data['MultiDeviceAccess'])

DeviceRegistered_encoder = LabelEncoder()
train_data['DeviceRegistered'] = DeviceRegistered_encoder.fit_transf
orm(train_data['DeviceRegistered'])

GenrePreference_encoder = LabelEncoder()
train_data['GenrePreference'] = GenrePreference_encoder.fit_transfor
m(train_data['GenrePreference'])

Gender_encoder = LabelEncoder()
train_data['Gender'] = Gender_encoder.fit_transform(train_data['Gend
er'])

ParentalControl_encoder = LabelEncoder()
train_data['ParentalControl'] = ParentalControl_encoder.fit_transfor
m(train_data['ParentalControl'])

SubtitlesEnabled_encoder = LabelEncoder()
train_data['SubtitlesEnabled'] = SubtitlesEnabled_encoder.fit_transf
orm(train_data['SubtitlesEnabled'])
```

In [44]:
```
#Encoding on Training data
SubscriptionType_encoder=LabelEncoder()
df['SubscriptionType']=SubscriptionType_encoder.fit_transform(df['S

PaymentMethod_encoder=LabelEncoder()
df['PaymentMethod']=PaymentMethod_encoder.fit_transform(df['PaymentI

PaperlessBilling_encoder=LabelEncoder()
df['PaperlessBilling']=PaperlessBilling_encoder.fit_transform(df['P

ContentType_encoder=LabelEncoder()
df['ContentType']=ContentType_encoder.fit_transform(df['ContentType

MultiDeviceAccess_encoder=LabelEncoder()
df['MultiDeviceAccess']=MultiDeviceAccess_encoder.fit_transform(df[
```

```python
DeviceRegistered_encoder=LabelEncoder()
df['DeviceRegistered']=DeviceRegistered_encoder.fit_transform(df['D

GenrePreference_encoder=LabelEncoder()
df['GenrePreference']=GenrePreference_encoder.fit_transform(df['Gen

Gender_encoder=LabelEncoder()
df['Gender']=Gender_encoder.fit_transform(df['Gender'])

ParentalControl_encoder=LabelEncoder()
df['ParentalControl']=ParentalControl_encoder.fit_transform(df['Par

SubtitlesEnabled_encoder=LabelEncoder()
df['SubtitlesEnabled']=SubtitlesEnabled_encoder.fit_transform(df['S
```

In [46]:
```python
df[categorical_columns].sample(5)
```

Out[46]:

	SubscriptionType	PaymentMethod	PaperlessBilling	ContentType
59489	1	0	0	2
3387	1	2	0	1
66677	0	1	1	2
142968	2	1	1	1
82231	2	0	1	2

In [48]:
```python
#Encoding Categorical Columns of Testing Data
for col in categorical_columns:
    print()
    print(f"#{col}")
    print(f"df1['{col}']={col}_encoder.transform(df['{col}'])")
```

```python
#SubscriptionType
df1['SubscriptionType']=SubscriptionType_encoder.transform(df['Subsc
riptionType'])

#PaymentMethod
df1['PaymentMethod']=PaymentMethod_encoder.transform(df['PaymentMeth
od'])

#PaperlessBilling
df1['PaperlessBilling']=PaperlessBilling_encoder.transform(df['Paper
lessBilling'])

#ContentType
df1['ContentType']=ContentType_encoder.transform(df['ContentType'])

#MultiDeviceAccess
df1['MultiDeviceAccess']=MultiDeviceAccess_encoder.transform(df['Mul
tiDeviceAccess'])

#DeviceRegistered
df1['DeviceRegistered']=DeviceRegistered_encoder.transform(df['Devic
eRegistered'])

#GenrePreference
df1['GenrePreference']=GenrePreference_encoder.transform(df['GenrePr
eference'])

#Gender
df1['Gender']=Gender_encoder.transform(df['Gender'])

#ParentalControl
df1['ParentalControl']=ParentalControl_encoder.transform(df['Parenta
lControl'])

#SubtitlesEnabled
df1['SubtitlesEnabled']=SubtitlesEnabled_encoder.transform(df['Subti
tlesEnabled'])
```

In [50]:
```python
import pandas as pd
from sklearn.preprocessing import OrdinalEncoder
categorical_columns = [
    'SubscriptionType', 'PaymentMethod', 'PaperlessBilling',
    'ContentType', 'MultiDeviceAccess', 'DeviceRegistered',
    'GenrePreference', 'Gender', 'ParentalControl', 'SubtitlesEnabl
encoder = OrdinalEncoder(handle_unknown='use_encoded_value', unknow

df[categorical_columns] = encoder.fit_transform(df[categorical_colu

df1[categorical_columns] = encoder.transform(df1[categorical_column

print("Transformed training data sample:")
print(df[categorical_columns].head())

print("\nTransformed test data sample:")
print(df1[categorical_columns].head())
```

Transformed training data sample:

	SubscriptionType	PaymentMethod	PaperlessBilling	ContentType
0	1.0	3.0	0.0	0.0
1	0.0	1.0	1.0	1.0
2	0.0	3.0	1.0	1.0
3	0.0	2.0	0.0	2.0
4	1.0	2.0	1.0	2.0

	MultiDeviceAccess	DeviceRegistered	GenrePreference	Gender
0	0.0	1.0	4.0	1.0
1	0.0	3.0	0.0	1.0
2	0.0	0.0	3.0	1.0
3	0.0	3.0	2.0	1.0
4	0.0	2.0	1.0	0.0

	ParentalControl	SubtitlesEnabled
0	0.0	0.0
1	0.0	1.0
2	1.0	1.0
3	1.0	1.0
4	0.0	0.0

Transformed test data sample:

	SubscriptionType	PaymentMethod	PaperlessBilling	ContentType
0	-1.0	-1.0	-1.0	-1.0
1	-1.0	-1.0	-1.0	-1.0
2	-1.0	-1.0	-1.0	-1.0
3	-1.0	-1.0	-1.0	-1.0
4	-1.0	-1.0	-1.0	-1.0

	MultiDeviceAccess	DeviceRegistered	GenrePreference	Gender
0	-1.0	-1.0	-1.0	-1.0
1	-1.0	-1.0	-1.0	-1.0
2	-1.0	-1.0	-1.0	-1.0
3	-1.0	-1.0	-1.0	-1.0
4	-1.0	-1.0	-1.0	-1.0

	ParentalControl	SubtitlesEnabled
0	-1.0	-1.0
1	-1.0	-1.0
2	-1.0	-1.0
3	-1.0	-1.0
4	-1.0	-1.0

In [52]:
```python
import numpy as np
from sklearn.preprocessing import StandardScaler

for col in numerical_columns:
    scaler_name = f"{col}_scaler"
    print()
    print(f"#{col}")
    print(f"{scaler_name} = StandardScaler()")
    print(f"train_data['{col}'] = {scaler_name}.fit_transform(np.ar
```

```python
#AccountAge
AccountAge_scaler = StandardScaler()
train_data['AccountAge'] = AccountAge_scaler.fit_transform(np.array(
train_data['AccountAge']).reshape(-1, 1))

#ContentDownloadsPerMonth
ContentDownloadsPerMonth_scaler = StandardScaler()
train_data['ContentDownloadsPerMonth'] = ContentDownloadsPerMonth_sc
aler.fit_transform(np.array(train_data['ContentDownloadsPerMonth']).
reshape(-1, 1))

#SupportTicketsPerMonth
SupportTicketsPerMonth_scaler = StandardScaler()
train_data['SupportTicketsPerMonth'] = SupportTicketsPerMonth_scale
r.fit_transform(np.array(train_data['SupportTicketsPerMonth']).resha
pe(-1, 1))

#WatchlistSize
WatchlistSize_scaler = StandardScaler()
train_data['WatchlistSize'] = WatchlistSize_scaler.fit_transform(np.
array(train_data['WatchlistSize']).reshape(-1, 1))
```

In [54]: `df[numerical_columns].sample(3)`

Out[54]:

	AccountAge	ContentDownloadsPerMonth	SupportTicketsPerMonth
69584	62	48	4
91838	12	21	0
81022	55	30	0

In [56]:
```python
#AccountAge
AccountAge_scaler=StandardScaler()
df['AccountAge']=AccountAge_scaler.fit_transform(np.array(df['Accou

#MonthlyCharges
MonthlyCharges_scaler=StandardScaler()
df['MonthlyCharges']=MonthlyCharges_scaler.fit_transform(np.array(d

#TotalCharges
TotalCharges_scaler=StandardScaler()
df['TotalCharges']=TotalCharges_scaler.fit_transform(np.array(df['T

#ViewingHoursPerWeek
ViewingHoursPerWeek_scaler=StandardScaler()
df['ViewingHoursPerWeek']=ViewingHoursPerWeek_scaler.fit_transform(

#AverageViewingDuration
AverageViewingDuration_scaler=StandardScaler()
df['AverageViewingDuration']=AverageViewingDuration_scaler.fit_tran

#ContentDownloadsPerMonth
ContentDownloadsPerMonth_scaler=StandardScaler()
df['ContentDownloadsPerMonth']=ContentDownloadsPerMonth_scaler.fit_
```

```python
#UserRating
UserRating_scaler=StandardScaler()
df['UserRating']=UserRating_scaler.fit_transform(np.array(df['UserR

#SupportTicketsPerMonth
SupportTicketsPerMonth_scaler=StandardScaler()
df['SupportTicketsPerMonth']=SupportTicketsPerMonth_scaler.fit_tran

#WatchlistSize
WatchlistSize_scaler=StandardScaler()
df['WatchlistSize']=WatchlistSize_scaler.fit_transform(np.array(df[
```

In [58]:
```python
df[numerical_columns].sample(3)
```

Out[58]:

	AccountAge	ContentDownloadsPerMonth	SupportTicketsPerMonth
59517	-0.352450	0.311798	1.216976
226062	1.426750	-0.589656	-1.568014
111791	-0.498286	0.866539	-1.568014

In [60]:
```python
df1[numerical_columns].sample(3)
```

Out[60]:

	AccountAge	ContentDownloadsPerMonth	SupportTicketsPerMonth	V
76196	17	44	1	
21516	2	29	2	
28728	99	11	1	

In [62]:
```python
#Feature Scaling
from sklearn.preprocessing import StandardScaler
for col in numerical_columns:
    print()
    print(f"#{col}")
    print(f"test_data['{col}']={col}_scaler.transform(np.array(test
```

```python
#AccountAge
test_data['AccountAge']=AccountAge_scaler.transform(np.array(test_da
ta['AccountAge']).reshape(len(test_data['AccountAge']),1))

#ContentDownloadsPerMonth
test_data['ContentDownloadsPerMonth']=ContentDownloadsPerMonth_scale
r.transform(np.array(test_data['ContentDownloadsPerMonth']).reshape(
len(test_data['ContentDownloadsPerMonth']),1))

#SupportTicketsPerMonth
test_data['SupportTicketsPerMonth']=SupportTicketsPerMonth_scaler.tr
ansform(np.array(test_data['SupportTicketsPerMonth']).reshape(len(te
st_data['SupportTicketsPerMonth']),1))

#WatchlistSize
test_data['WatchlistSize']=WatchlistSize_scaler.transform(np.array(t
est_data['WatchlistSize']).reshape(len(test_data['WatchlistSize']),
1))
```

ML Model

```python
In [112…   from sklearn.model_selection import train_test_split
           from sklearn.preprocessing import StandardScaler, LabelEncoder
           from sklearn.impute import SimpleImputer
           from sklearn.naive_bayes import GaussianNB
           from sklearn.linear_model import LogisticRegression
           from sklearn.tree import DecisionTreeClassifier
           from sklearn.neighbors import KNeighborsClassifier
           from sklearn.metrics import accuracy_score, precision_score, recall
```

```python
In [114…   num_features = df.select_dtypes(include=["number"]).columns
           cat_features = df.select_dtypes(include=["object"]).columns

           imputer = SimpleImputer(strategy="median")
           df[num_features] = imputer.fit_transform(df[num_features])
           if len(cat_features) > 0:
               encoders = {col: LabelEncoder() for col in cat_features}
               for col, encoder in encoders.items():
                   df[col] = encoder.fit_transform(df[col])

           X = df.drop(columns=["Churn"], errors="ignore")
           y = df["Churn"]

           scaler = StandardScaler()
           X_scaled = scaler.fit_transform(X)

           X_train, X_test, y_train, y_test = train_test_split(
               X_scaled, y, test_size=0.25, stratify=y, random_state=42
           )

           models = {
               "Naive Bayes": GaussianNB(),
               "Logistic Regression": LogisticRegression(),
               "Decision Tree": DecisionTreeClassifier(max_depth=4),
               "KNN": KNeighborsClassifier(n_neighbors=5)
           }
```

```python
f1_scores = []

for name, model in models.items():
    model.fit(X_train, y_train)
    y_pred = model.predict(X_test)

    acc = accuracy_score(y_test, y_pred)
    precision = precision_score(y_test, y_pred)
    recall = recall_score(y_test, y_pred)
    f1 = f1_score(y_test, y_pred)
    roc_auc = roc_auc_score(y_test, y_pred)

    print(f"\n Model: {name}")
    print(f"   Accuracy  : {acc:.4f}")
    print(f"   Precision : {precision:.4f}")
    print(f"   Recall    : {recall:.4f}")
    print(f"   F1 Score  : {f1:.4f}")
    print(f"   ROC AUC   : {roc_auc:.4f}")

    f1_scores.append((f1, name))

# Print sorted F1 scores
f1_scores.sort(reverse=True)
print("\nSorted F1 Scores:", f1_scores)
```

```
Model: Naive Bayes
   Accuracy  : 0.7947
   Precision : 0.4158
   Recall    : 0.3274
   F1 Score  : 0.3664
   ROC AUC   : 0.6128

Model: Logistic Regression
   Accuracy  : 0.8242
   Precision : 0.5760
   Recall    : 0.1145
   F1 Score  : 0.1911
   ROC AUC   : 0.5479

Model: Decision Tree
   Accuracy  : 0.8188
   Precision : 0.0000
   Recall    : 0.0000
   F1 Score  : 0.0000
   ROC AUC   : 0.5000

Model: KNN
   Accuracy  : 0.7983
   Precision : 0.3522
   Recall    : 0.1349
   F1 Score  : 0.1951
   ROC AUC   : 0.5400
```

Sorted F1 Scores: [(0.36637123322360093, 'Naive Bayes'), (0.19507724 535218643, 'KNN'), (0.19105875245431203, 'Logistic Regression'), (0. 0, 'Decision Tree')]

SMOTE: DECISION TREE

In [117…
```python
import pandas as pd
import matplotlib.pyplot as plt
from imblearn.over_sampling import SMOTE
X = df.drop('Churn', axis=1)
y = df['Churn']
original_churn_count = (y == 1).sum()
original_not_churn_count = (y == 0).sum()
original_total_count = len(y)
original_percentage_churn = (original_churn_count / original_total_
original_percentage_not_churn = (original_not_churn_count / origina

print("*** Before SMOTE ***")
print("Percentage of 'Churn':", original_percentage_churn)
print("Percentage of 'Not Churn':", original_percentage_not_churn)
smote = SMOTE(sampling_strategy=0.25, random_state=42)
X_resampled, y_resampled = smote.fit_resample(X, y)

churn_count = (y_resampled == 1).sum()
not_churn_count = (y_resampled == 0).sum()

total_count = len(y_resampled)
percentage_churn = (churn_count / total_count) * 100
```

```python
percentage_not_churn = (not_churn_count / total_count) * 100

print("\n*** After SMOTE ***")
print("Percentage of 'Churn':", percentage_churn)
print("Percentage of 'Not Churn':", percentage_not_churn)
```

```
*** Before SMOTE ***
Percentage of 'Churn': 18.123197709475892
Percentage of 'Not Churn': 81.87680229052411

*** After SMOTE ***
Percentage of 'Churn': 19.999919841607017
Percentage of 'Not Churn': 80.00008015839299
```

In [119…
```python
from imblearn.over_sampling import RandomOverSampler
ros = RandomOverSampler(random_state=42)
X_train_resampled, y_train_resampled = ros.fit_resample(X_train, y_
y_train_resampled_series = pd.Series(y_train_resampled, name='Churn
resampled_data = pd.concat([pd.DataFrame(X_train_resampled), y_trai
X_resampled = resampled_data.drop('Churn', axis=1)
y_resampled = resampled_data['Churn']
X_train, X_test, y_train, y_test = train_test_split(X_resampled, y_
```

In [267…
```python
churn_count = resampled_data['Churn'].sum()
not_churn_count = len(resampled_data) - churn_count
total_count = len(resampled_data)
percentage_churn = (churn_count / total_count) * 100
percentage_not_churn = (not_churn_count / total_count) * 100
print("*** After sampling ***")
print(f"Percentage of 'Churn': {percentage_churn:.2f}%")
print(f"Percentage of 'Not Churn': {percentage_not_churn:.2f}%")
labels = ['Churn', 'Not Churn']
sizes = [percentage_churn, percentage_not_churn]
```

```
*** After sampling ***
Percentage of 'Churn': 50.00%
Percentage of 'Not Churn': 50.00%
```

Hyperparameter Optimization with RandomizedSearchCV

In [142…
```python
params = {"max_depth": range(2, 15),
          "n_estimators": range(10, 50),
          "min_samples_split": [2, 3, 4],
          "max_features": ["sqrt", "log", None,  "auto"],
          "criterion": ["gini", "entropy"]}
```

In [144…
```python
rf_random = RandomizedSearchCV(estimator=model, param_distributions
```

In [146…
```python
rf_random.fit(X_train, y_train)
```

Out[146…

```
▸        RandomForestCV                    ⓘ ?

▸        best_estimator_:
         RandomForestClassifier

   ▸  RandomForestClassifier    ?
```
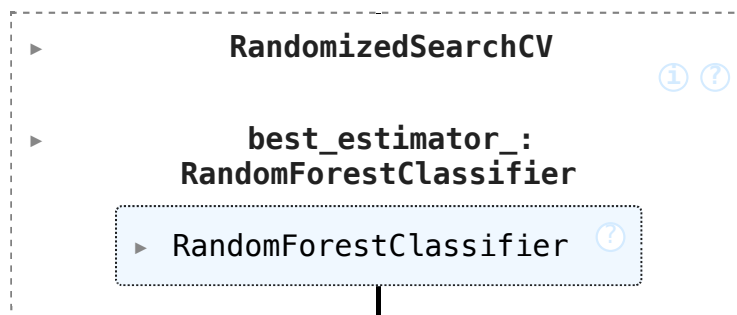
In [160…
```python
print("Best Params-->", rf_random.best_params_)
print("Best Score-->", rf_random.best_score_)
```

```
Best Params--> {'n_estimators': 28, 'min_samples_split': 3, 'max_fea
tures': None, 'max_depth': 13, 'criterion': 'gini'}
Best Score--> 0.7955120326332853
```

In [156…
```python
model_tuned = model.set_params(**rf_random.best_params_).fit(X_trai
```

In [162…
```python
y_pred = model_tuned.predict(X_test)
print(classification_report(y_test, y_pred))


y_prob = model_tuned.predict_proba(X_test)[:, 1]
roc_auc = roc_auc_score(y_test, y_prob)
print(f"ROC AUC: {roc_auc}")
```

```
              precision    recall  f1-score   support

         0.0       0.86      0.75      0.80     37392
         1.0       0.78      0.88      0.83     37460

    accuracy                           0.81     74852
   macro avg       0.82      0.81      0.81     74852
weighted avg       0.82      0.81      0.81     74852

ROC AUC: 0.8905076176248247
```

In [167…
```python
from sklearn.model_selection import GridSearchCV

param_grid = {
    "max_depth": [15, 17],
    "n_estimators": [40, 50, 70]
}

rf_search = GridSearchCV(
    estimator=model,
    param_grid=param_grid,
    cv=2,
    scoring="f1",
    n_jobs=-1,
    verbose=2
)

rf_search.fit(X_train, y_train)
```

```
Fitting 2 folds for each of 6 candidates, totalling 12 fits
[CV] END ......................max_depth=15, n_estimators=40; total
time=  53.5s
[CV] END ......................max_depth=15, n_estimators=40; total
time=  54.4s
[CV] END ......................max_depth=17, n_estimators=40; total
time=  57.7s
[CV] END ......................max_depth=17, n_estimators=40; total
time=  57.9s
[CV] END ......................max_depth=15, n_estimators=50; total
time= 1.1min
[CV] END ......................max_depth=15, n_estimators=50; total
time= 1.1min
[CV] END ......................max_depth=15, n_estimators=70; total
time= 1.6min
[CV] END ......................max_depth=15, n_estimators=70; total
time= 1.6min
[CV] END ......................max_depth=17, n_estimators=50; total
time= 1.1min
[CV] END ......................max_depth=17, n_estimators=50; total
time= 1.1min
[CV] END ......................max_depth=17, n_estimators=70; total
time= 1.3min
[CV] END ......................max_depth=17, n_estimators=70; total
time= 1.3min
```

Out[167…

> **GridSearchCV**   ⓘ ⑦

> **best_estimator_:
> RandomForestClassifier**

> ▸ RandomForestClassifier   ⑦
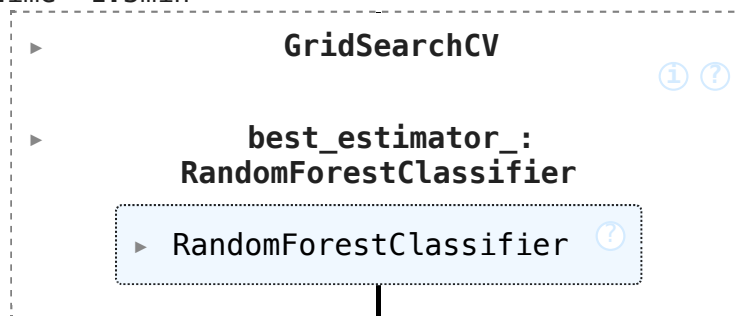
In [173…
```python
print("Best Parameters:", rf_search.best_params_)
print("Best F1 Score:", rf_search.best_score_)
```

```
Best Parameters: {'max_depth': 17, 'n_estimators': 70}
Best F1 Score: 0.8520966723696461
```

In [177…
```python
model_tuned = model_tuned.set_params(**rf_search.best_params_).fit(
```

In [179…
```python
from sklearn.metrics import classification_report, roc_auc_score


y_pred = model_tuned.predict(X_test)
y_prob = model_tuned.predict_proba(X_test)[:, 1]


print(classification_report(y_test, y_pred))
print(f"ROC AUC: {roc_auc_score(y_test, y_prob)}")
```

```
              precision    recall  f1-score   support

         0.0       0.97      0.84      0.90     37392
         1.0       0.86      0.97      0.91     37460

    accuracy                           0.91     74852
   macro avg       0.91      0.91      0.91     74852
weighted avg       0.91      0.91      0.91     74852
```

ROC AUC: 0.9789906844865017

In [181…
```python
train_predictions = model_tuned.predict(X_train)
print(classification_report(y_train, train_predictions))

train_probabilities = model_tuned.predict_proba(X_train)[:, 1]
print(f"roc_auc --> {roc_auc_score(y_train, train_probabilities)}")
```

```
              precision    recall  f1-score   support

         0.0       1.00      0.96      0.98    112312
         1.0       0.96      1.00      0.98    112244

    accuracy                           0.98    224556
   macro avg       0.98      0.98      0.98    224556
weighted avg       0.98      0.98      0.98    224556
```

roc_auc --> 0.9993045450664235

In [185…
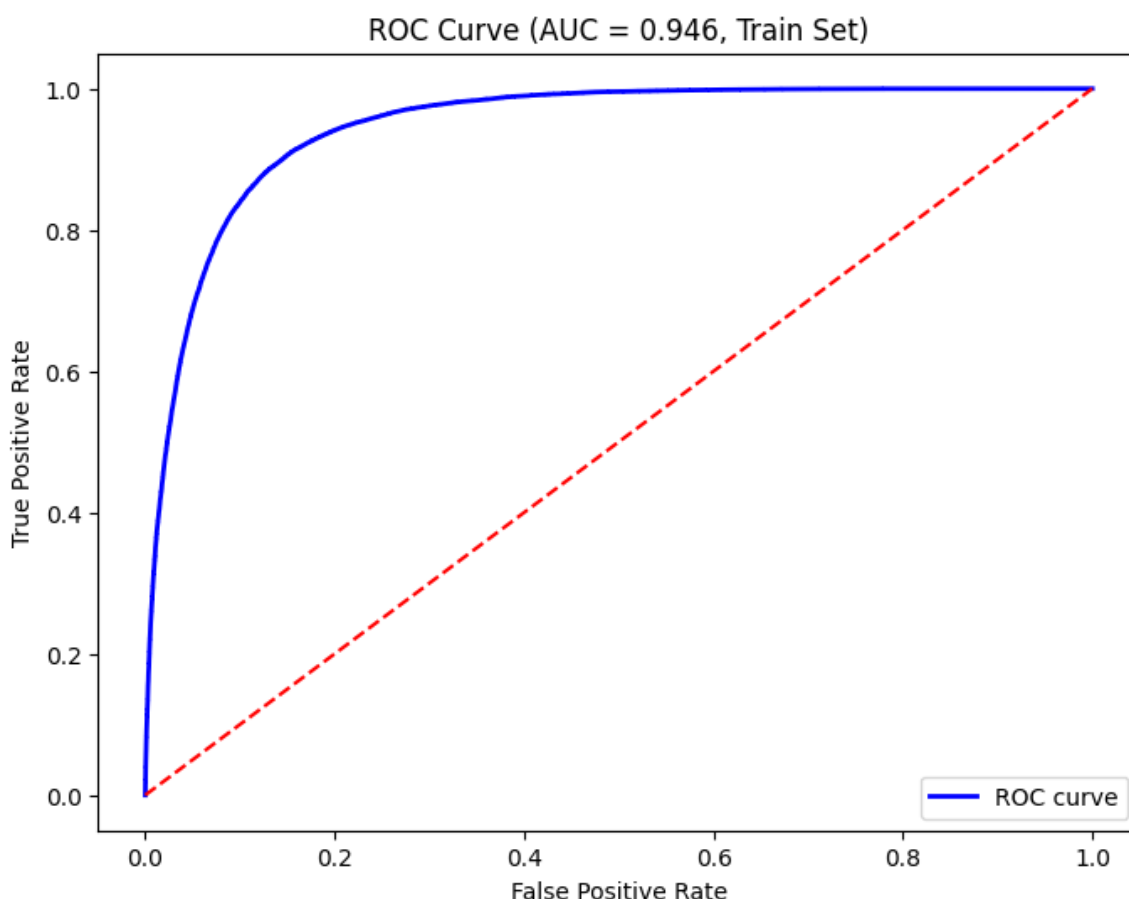
```python
In [189…    # Train Set K-Fold Cross Validation
           cv_results = cross_validate(model_tuned,
                                       X_train, y_train,
                                       cv=5,
                                       scoring=["accuracy", "precision", "reca

           print("Accuracy:", round(cv_results["test_accuracy"].mean(), 2))
           print("Precision:", round(cv_results["test_precision"].mean(), 2))
           print("Recall:", round(cv_results["test_recall"].mean(), 2))
           print("f1:", round(cv_results["test_f1"].mean(), 2))
           print("roc_auc:", round(cv_results["test_roc_auc"].mean(), 2))
```

```
Accuracy: 0.89
Precision: 0.84
Recall: 0.96
f1: 0.9
roc_auc: 0.97
```

FEATURE IMPORTANCE

```python
In [192…    def plot_feature_improtances(model, feature, num=len(X)):
               feature_imp = pd.DataFrame({"Value": model.feature_importances_
                                           "Name": feature.columns})
               plt.figure(figsize=(20, 12))
               sns.barplot(x="Value", y="Name", data=feature_imp.sort_values("
               plt.title("Feature Importances", fontsize=30)
               plt.xlabel("Value", fontsize=30)
               plt.ylabel("Name", fontsize=30)
               plt.show()

           plot_feature_improtances(model_tuned, X_test)
```
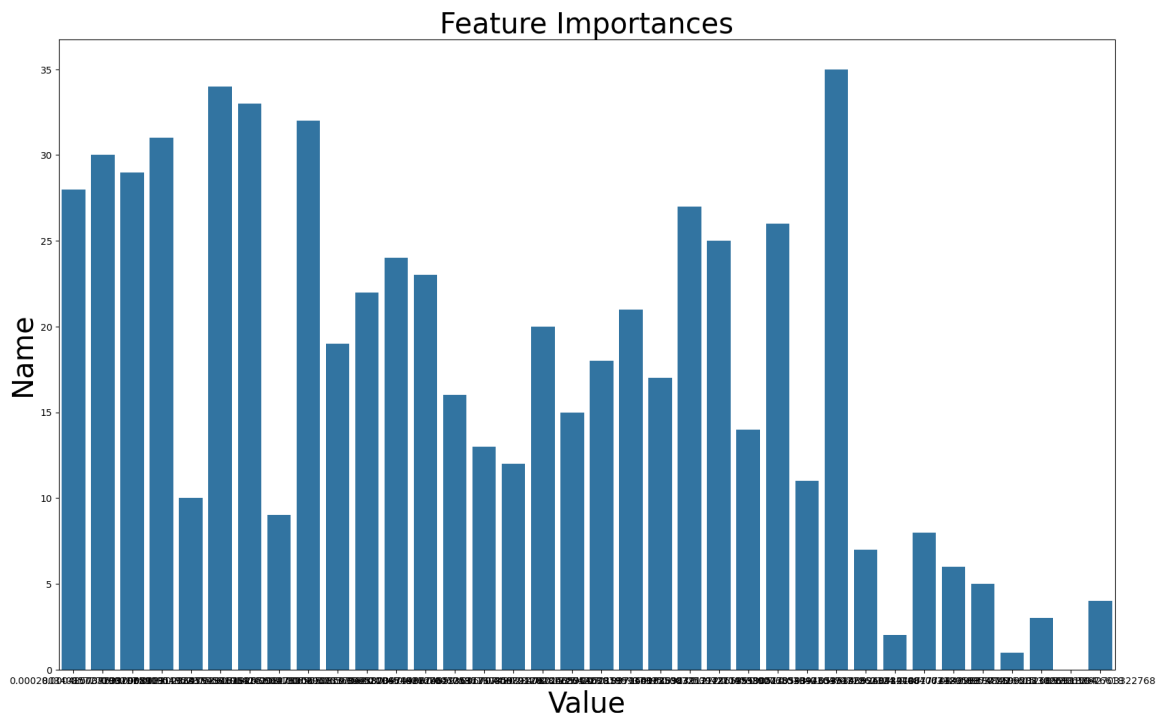

Hyperparameter Optimization w RandomizedSearchCV

```python
In [205…    params = {"criterion": ["gini", "entropy"],
```

```python
            "max_depth": range(2, 30),
            "splitter": ["best", "random"],
            "min_samples_split": range(2, 10),
            "min_samples_leaf": range(1, 5),
            "max_features": ["auto", "sqrt", "log2", 3, 5, 7]}

cart_random = RandomizedSearchCV(estimator=cart_model,
                                 param_distributions=params,
                                 cv=3,
                                 random_state=42,
                                 n_iter=100, n_jobs=-1)
cart_random.fit(X_train, y_train)
```

Out[205…

▸   **RandomizedSearchCV**
                                              ⓘ ⍰

▸   **best_estimator_:**
             DecisionTreeClassifier

  ▸ DecisionTreeClassifier   ⍰
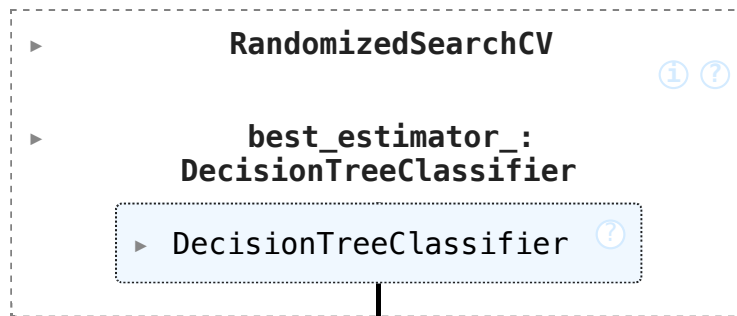
In [207…
```python
print("Best Parameters-->", cart_random.best_params_)
print("Best Score-->", cart_random.best_score_)
```

```
Best Parameters--> {'splitter': 'random', 'min_samples_split': 2, 'm
in_samples_leaf': 1, 'max_features': 5, 'max_depth': 24, 'criterio
n': 'entropy'}
Best Score--> 0.7973443027756013
```

TUNED MODEL

In [210…
```python
cart_tuned_model = cart_model.set_params(**cart_random.best_params_
```

In [216…
```python
plot_feature_improtances(cart_tuned_model, X_test)
```

Feature Importances
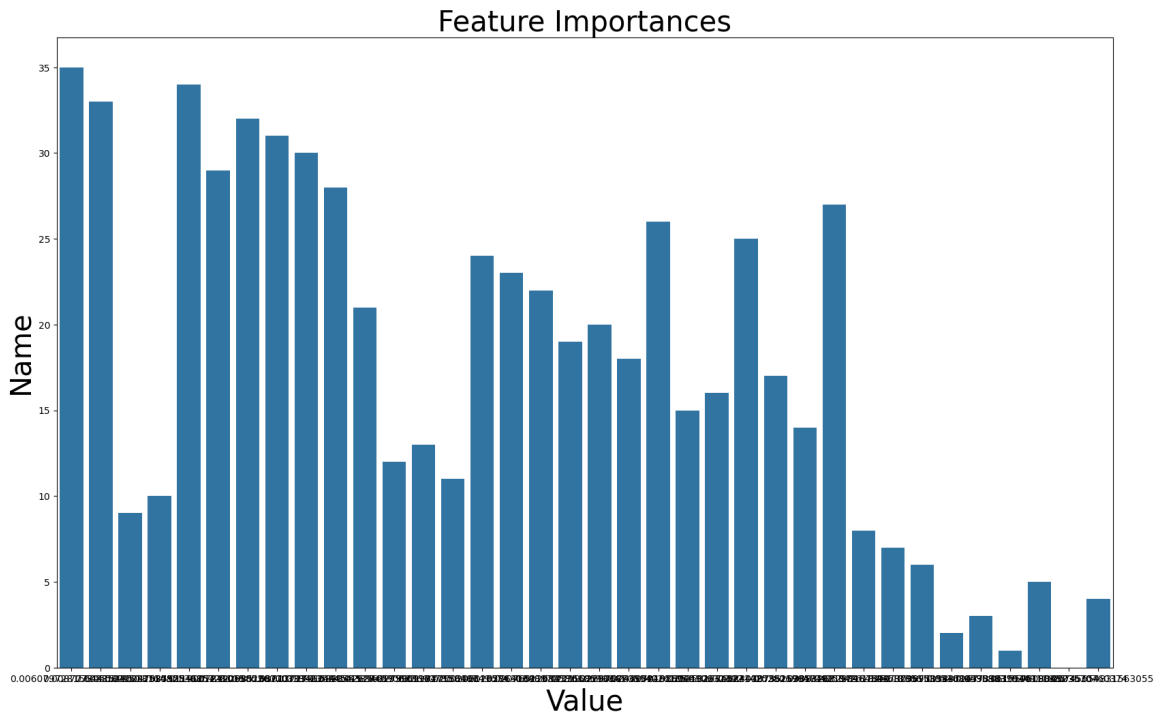
SMOTE LightGBM Model After Feature Selection

In [224…
```
df2 = df_.copy()
df2.head()
```

Out[224…

	AccountAge	MonthlyCharges	TotalCharges	SubscriptionType	PaymentM
0	20	11.055215	221.104302	Premium	Mailed
1	57	5.175208	294.986882	Basic	Cred
2	73	12.106657	883.785952	Basic	Mailed
3	32	7.263743	232.439774	Basic	Electronic
4	57	16.953078	966.325422	Premium	Electronic

In [226…
```
df2.drop(["PaymentMethod", "PaperlessBilling", "GenrePreference", "
          "SupportTicketsPerMonth", "ParentalControl", "DeviceRegis
df2.head()
```

Out[226…

	AccountAge	MonthlyCharges	TotalCharges	SubscriptionType	MultiDevic
0	20	11.055215	221.104302	Premium	
1	57	5.175208	294.986882	Basic	
2	73	12.106657	883.785952	Basic	
3	32	7.263743	232.439774	Basic	
4	57	16.953078	966.325422	Premium	

In [228…
```
cat_var, cat_but_car, num_var = grab_variable(df2)
```

```
Observation: 243787
Number of Variables: 12
Number of Categoric Variables: 4
Number of Num but Cat Variables: 1
Number of Cat but Cardinal Variables: 0
Number of Numeric Variables: 8
```

In [230…
```python
cat_var.remove("Churn")
df2 = pd.get_dummies(data=df2, columns=cat_var, dtype="int64", drop
df2.head()
```

Out[230…

	AccountAge	MonthlyCharges	TotalCharges	ViewingHoursPerWeek	Avera
0	20	11.055215	221.104302	36.758104	
1	57	5.175208	294.986882	32.450568	
2	73	12.106657	883.785952	7.395160	
3	32	7.263743	232.439774	27.960389	
4	57	16.953078	966.325422	20.083397	

In [234…
```python
scaler = StandardScaler()
df2[num_var] = scaler.fit_transform(df2[num_var])
```

In [236…
```python
X = df2.drop("Churn", axis=1)
y = df2["Churn"]

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size

smote = SMOTE(random_state=42)
X_train_resampled, y_train_resampled = smote.fit_resample(X_train,

resampled_data = pd.concat([X_train_resampled, pd.Series(y_train_re

X_resampled = resampled_data.drop('Churn', axis=1)
y_resampled = resampled_data['Churn']

X_train, X_test, y_train, y_test = train_test_split(X_resampled, y_
                                                    test_size=0.20,
                                                    random_state=42
```

In [238…
```python
smote_lgbm = LGBMClassifier(random_state=42, verbosity=-1)
smote_lgbm.fit(X_train, y_train)
```

Out[238…

```
▼                      LGBMClassifier                        ⓘ

LGBMClassifier(random_state=42, verbosity=-1)
```

In [240…
```python
# Test Set
y_pred = smote_lgbm.predict(X_test)
y_prob = smote_lgbm.predict_proba(X_test)[:, 1]
print("Classification Report\n", classification_report(y_test, y_pr
print("roc_auc-->", roc_auc_score(y_test, y_prob))
```

```
Classification Report
               precision    recall   f1-score    support

           0        0.83      0.96       0.89      32030
           1        0.96      0.79       0.87      31825

    accuracy                            0.88      63855
   macro avg        0.89      0.88       0.88      63855
weighted avg        0.89      0.88       0.88      63855
```

roc_auc--> 0.9371255708574467

In [269…
```python
# Train Set
y_pred_train = smote_lgbm.predict(X_train)
y_prob_train = smote_lgbm.predict_proba(X_train)[:, 1]
print("Classification Report\n", classification_report(y_train, y_p
print("roc_auc-->", roc_auc_score(y_train, y_prob_train))
```

```
Classification Report
               precision    recall   f1-score    support

           0        0.83      0.98       0.90     127607
           1        0.98      0.80       0.88     127812

    accuracy                            0.89     255419
   macro avg        0.90      0.89       0.89     255419
weighted avg        0.90      0.89       0.89     255419
```

roc_auc--> 0.9479497813119485

Hyperparameter Optimization

In [245…
```python
smote_lgbm.get_params()
```

Out[245…
```python
{'boosting_type': 'gbdt',
 'class_weight': None,
 'colsample_bytree': 1.0,
 'importance_type': 'split',
 'learning_rate': 0.1,
 'max_depth': -1,
 'min_child_samples': 20,
 'min_child_weight': 0.001,
 'min_split_gain': 0.0,
 'n_estimators': 100,
 'n_jobs': None,
 'num_leaves': 31,
 'objective': None,
 'random_state': 42,
 'reg_alpha': 0.0,
 'reg_lambda': 0.0,
 'subsample': 1.0,
 'subsample_for_bin': 200000,
 'subsample_freq': 0,
 'verbosity': -1}
```

In [247…
```python
params = {"max_depth": range(-1, 5),
```

```python
            "n_estimators": [100, 200, 300],
            "subsample": [0.6, 0.8, 1.0]}

smote_lgbm_cv = GridSearchCV(estimator=smote_lgbm,
                             param_grid=params,
                             cv=3,
                             scoring="f1",
                             n_jobs=-1).fit(X_train, y_train)
```

/opt/anaconda3/lib/python3.12/site-packages/sklearn/utils/_tags.py:3
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  warnings.warn(
```

In [248…
```python
print("Best Params-->", smote_lgbm_cv.best_params_)
print("Best Score-->", smote_lgbm_cv.best_score_)
```

```
Best Params--> {'max_depth': -1, 'n_estimators': 300, 'subsample':
0.6}
Best Score--> 0.8738630542942675
```

In [253…
```python
model_tuned = smote_lgbm.set_params(**smote_lgbm_cv.best_params_).f
```

In [255…
```python
# Test Set
y_pred = model_tuned.predict(X_test)
y_prob = model_tuned.predict_proba(X_test)[:, 1]
print("Classification Report\n", classification_report(y_test, y_pr
print("roc_auc-->", roc_auc_score(y_test, y_prob))
```

```
Classification Report
              precision    recall  f1-score   support

           0       0.83      0.97      0.90     32030
           1       0.97      0.80      0.87     31825

    accuracy                           0.89     63855
   macro avg       0.90      0.89      0.89     63855
weighted avg       0.90      0.89      0.89     63855

roc_auc--> 0.9395983125599798
```

In [257…
```python
# Train Set
y_pred_train = model_tuned.predict(X_train)
y_prob_train = model_tuned.predict_proba(X_train)[:, 1]
print("Classification Report\n", classification_report(y_train, y_p
print("roc_auc-->", roc_auc_score(y_train, y_prob_train))
```

Classification Report

	precision	recall	f1-score	support
0	0.83	0.98	0.90	127607
1	0.98	0.80	0.88	127812
accuracy			0.89	255419
macro avg	0.90	0.89	0.89	255419
weighted avg	0.90	0.89	0.89	255419

roc_auc--> 0.9479497813119485

In [259…
```python
# Prediction:
random_customer = X.sample(1)
random_customer
```

Out[259…

	AccountAge	MonthlyCharges	TotalCharges	ViewingHoursPerWeek
160957	-0.906627	-0.246074	-0.801789	-0.975257

In [261…
```python
df[df.index == random_customer.index[0]]["Churn"]
```

Out[261…
```
160957    0.0
Name: Churn, dtype: float64
```

In [263…
```python
print("Prediction Outcome for Random Customer:\t", model_tuned.pred
```

Prediction Outcome for Random Customer: [0]

In [265…
```python
Analyzing model complexity with Learning Curves
from sklearn.model_selection import validation_curve

train_score, test_score = validation_curve(model_tuned,
                                           X, y,
                                           cv=2,
                                           param_name="max_depth",
                                           param_range=range(1, 10)
                                           scoring="roc_auc")

mean_train_score = np.mean(train_score, axis=1)
mean_test_score = np.mean(test_score, axis=1)
print("Train Score Mean-->", mean_train_score)
print("Test Score Mean-->", mean_test_score)

plt.plot(mean_train_score,
         label="Training Score", color="blue")

plt.plot(mean_test_score,
         label="Test / Validation Score", color="red")

plt.title("Validation Curve for max_depth")
plt.xlabel("Number of max_depth")
plt.ylabel("roc_auc")
plt.grid()
plt.legend(loc="best")
plt.show()
```
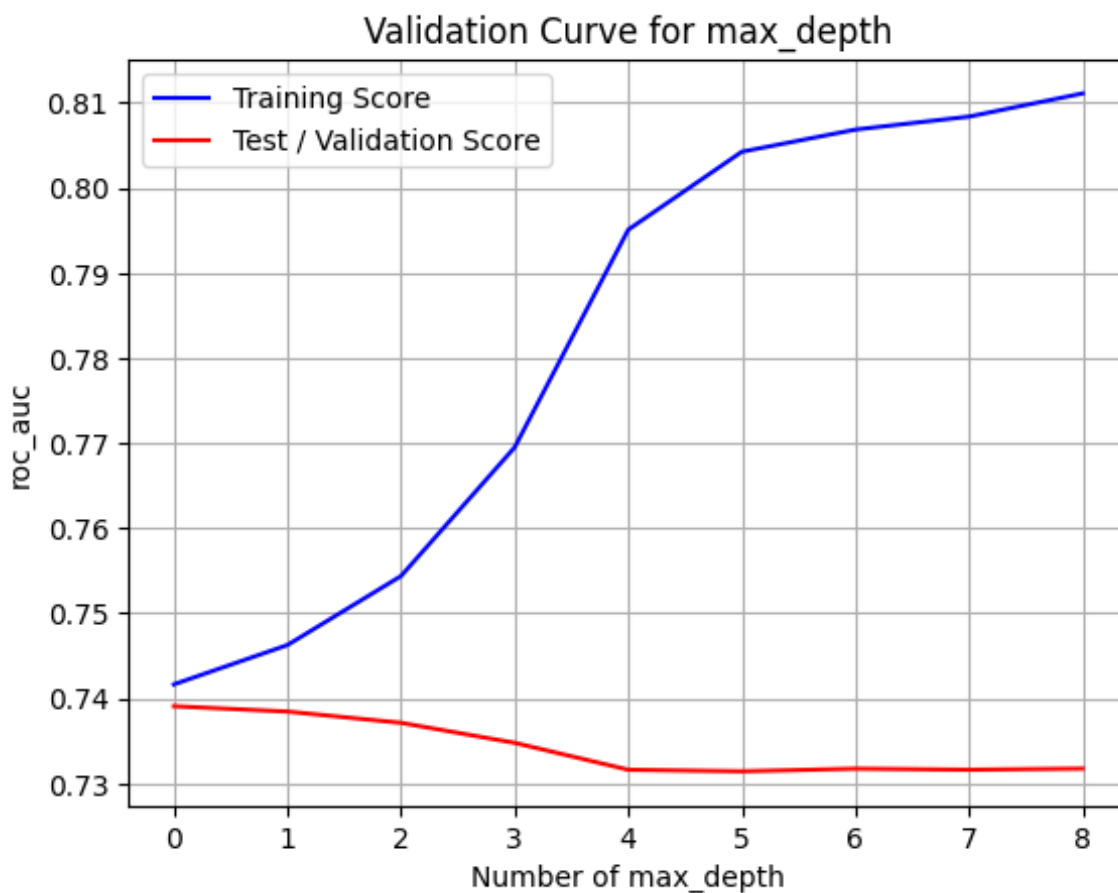
```
Train Score Mean--> [0.74163382 0.74625703 0.75437227 0.7695029  0.7
950894  0.80425379
 0.8068566  0.80838305 0.8111083 ]
Test Score Mean--> [0.7390679  0.73844189 0.73711705 0.73476147 0.73
159971 0.73141453
 0.73172336 0.73160186 0.7317342 ]
```


Validation Curve for max_depth