DATA DESCRIPTION:

This data set contains details of a bank's customers and the target variable is a binary variable reflecting the fact whether the customer left the bank (closed his account) or he continues to be a customer.

RowNumber: Row Numbers from 1 to 10000

CustomerId: Unique Ids for bank customer identification

Surname: Customer's last name

CreditScore: Credit score of the customer

Geography: The country from which the customer belongs

Gender: Male or Female

Age: Age of the customer

Tenure: Number of years for which the customer has been with the bank

Balance: Bank balance of the customer

NumOfProducts: Number of bank products the customer is utilising

HasCrCard: Binary Flag for whether the customer holds a credit card with the bank or not

IsActiveMember: Binary Flag for whether the customer is an active member with the bank or not

EstimatedSalary: Estimated salary of the customer in Dollars

Exited: Binary flag 1 if the customer closed account with bank and 0 if the customer is retained

> Target Column Description: Exited is a class label used to divide into groups (customer closed account or not).

In [1]:

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import warnings
warnings.filterwarnings('ignore')
df=pd.read_csv('Churn_Modelling.csv')
df.head()
```

Out[1]:

	RowNumber	CustomerId	Surname	CreditScore	Geography	Gender	Age	Tenure	Balance
0	1	15634602	Hargrave	619	France	Female	42	2	0.00
1	2	15647311	Hill	608	Spain	Female	41	1	83807.86
2	3	15619304	Onio	502	France	Female	42	8	159660.80
3	4	15701354	Boni	699	France	Female	39	1	0.00

	RowNumber	CustomerId	Surname	CreditScore	Geography	Gender	Age	Tenure	Balance	I
4	5	15737888	Mitchell	850	Spain	Female	43	2	125510.82	

In [2]:
```
df.shape
```
Out[2]:
```
(10000, 14)
```

In [3]:
```
df['HasCrCard'] = df['HasCrCard'].astype('object')
df['IsActiveMember'] = df['IsActiveMember'].astype('object')
df['Exited'] = df['Exited'].astype('object')
```

In [4]:
```
df_cat = df.select_dtypes('O')
df_cat.columns
```
Out[4]:
```
Index(['Surname', 'Geography', 'Gender', 'HasCrCard', 'IsActiveMember',
       'Exited'],
      dtype='object')
```

In [5]:
```
df_num = df.select_dtypes(np.number)
df_num.columns
```
Out[5]:
```
Index(['RowNumber', 'CustomerId', 'CreditScore', 'Age', 'Tenure', 'Balance',
       'NumOfProducts', 'EstimatedSalary'],
      dtype='object')
```

In [6]:
```
df_num.describe()
```
Out[6]:

	RowNumber	CustomerId	CreditScore	Age	Tenure	Balance	NumO
count	10000.00000	1.000000e+04	10000.000000	10000.000000	10000.000000	10000.000000	100
mean	5000.50000	1.569094e+07	650.528800	38.921800	5.012800	76485.889288	
std	2886.89568	7.193619e+04	96.653299	10.487806	2.892174	62397.405202	
min	1.00000	1.556570e+07	350.000000	18.000000	0.000000	0.000000	
25%	2500.75000	1.562853e+07	584.000000	32.000000	3.000000	0.000000	
50%	5000.50000	1.569074e+07	652.000000	37.000000	5.000000	97198.540000	
75%	7500.25000	1.575323e+07	718.000000	44.000000	7.000000	127644.240000	
max	10000.00000	1.581569e+07	850.000000	92.000000	10.000000	250898.090000	

In [7]:
```
df_cat.describe()
```
Out[7]:

	Surname	Geography	Gender	HasCrCard	IsActiveMember	Exited
count	10000	10000	10000	10000	10000	10000
unique	2932	3	2	2	2	2
top	Smith	France	Male	1	1	0

	Surname	Geography	Gender	HasCrCard	IsActiveMember	Exited
freq	32	5014	5457	7055	5151	7963

In [8]:

```
df.isnull().sum()
```

Out[8]:

```
RowNumber          0
CustomerId         0
Surname            0
CreditScore        0
Geography          0
Gender             0
Age                0
Tenure             0
Balance            0
NumOfProducts      0
HasCrCard          0
IsActiveMember     0
EstimatedSalary    0
Exited             0
dtype: int64
```

In [9]:

```
df.isnull().sum()/len(df)*100
```

Out[9]:

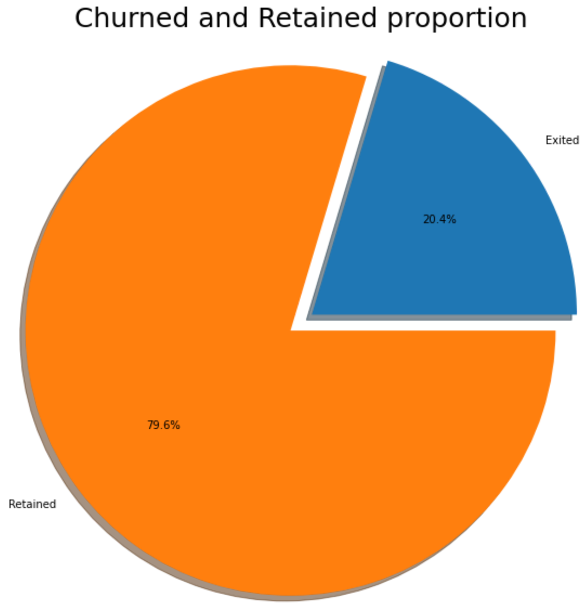
```
RowNumber          0.0
CustomerId         0.0
Surname            0.0
CreditScore        0.0
Geography          0.0
Gender             0.0
Age                0.0
Tenure             0.0
Balance            0.0
NumOfProducts      0.0
HasCrCard          0.0
IsActiveMember     0.0
EstimatedSalary    0.0
Exited             0.0
dtype: float64
```

In [10]:

```
df['Exited'] = df['Exited'].astype('int')
```

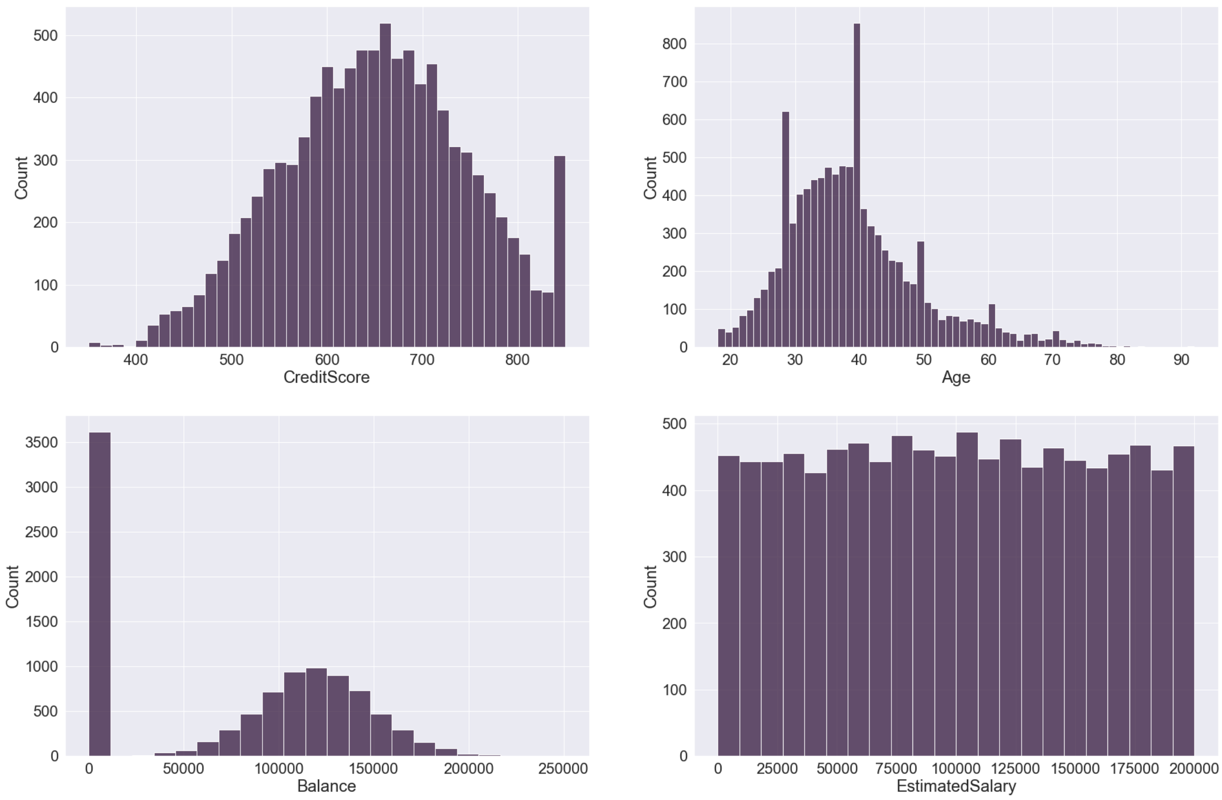
In [11]:

```
fig, axs = plt.subplots(figsize=(20, 10))
sizes = [df.Exited[df['Exited']==1].count(), df.Exited[df['Exited']==0].count()]
axs.pie(sizes, explode=(0, 0.1), labels=['Exited', 'Retained'], autopct='%1.1f%%',sh
axs.axis('equal')
plt.title("Churned and Retained proportion", size = 25)
plt.show()
```



In [12]:

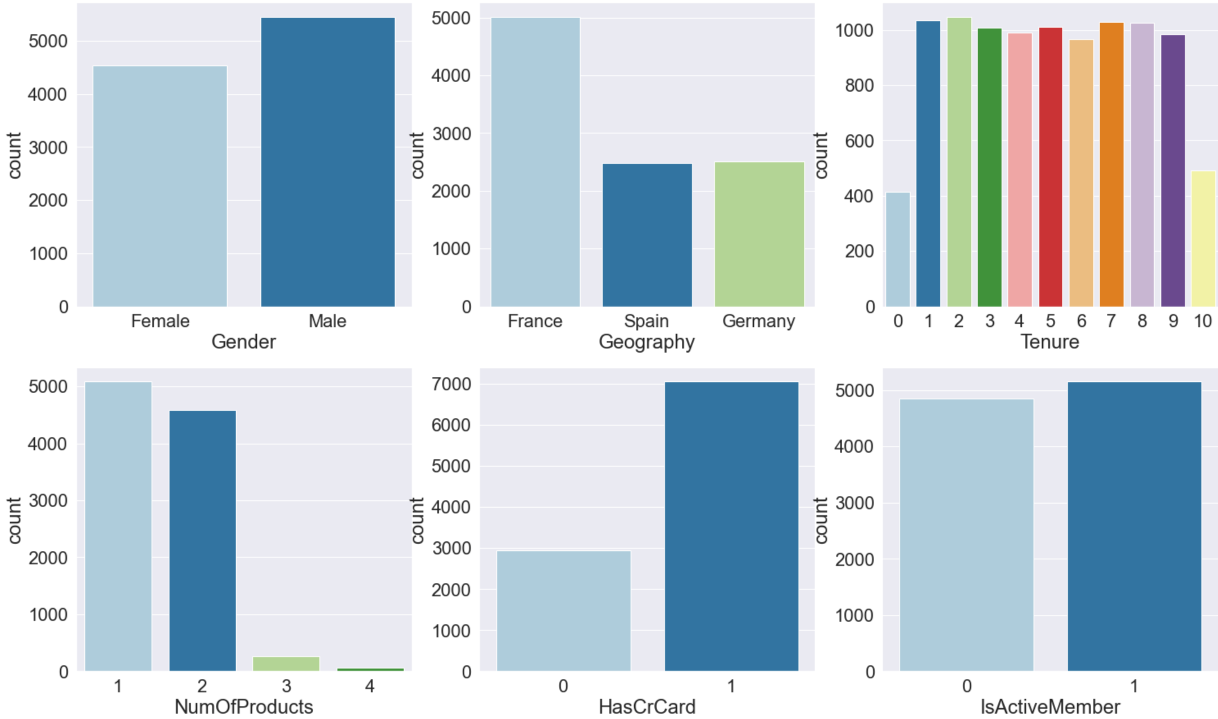
```
sns.set(rc={'figure.figsize':(30,20)})
sns.set(font_scale = 2)
fig,axs = plt.subplots(2,2)
sns.set_theme(palette="rocket")
sns.histplot(data = df,x = "CreditScore",ax=axs[0,0])
sns.histplot(data = df,x = "Age",ax=axs[0,1])
sns.histplot(data = df,x = "Balance",ax=axs[1,0])
sns.histplot(data = df,x = "EstimatedSalary",ax=axs[1,1])
plt.show()
```



In [13]:

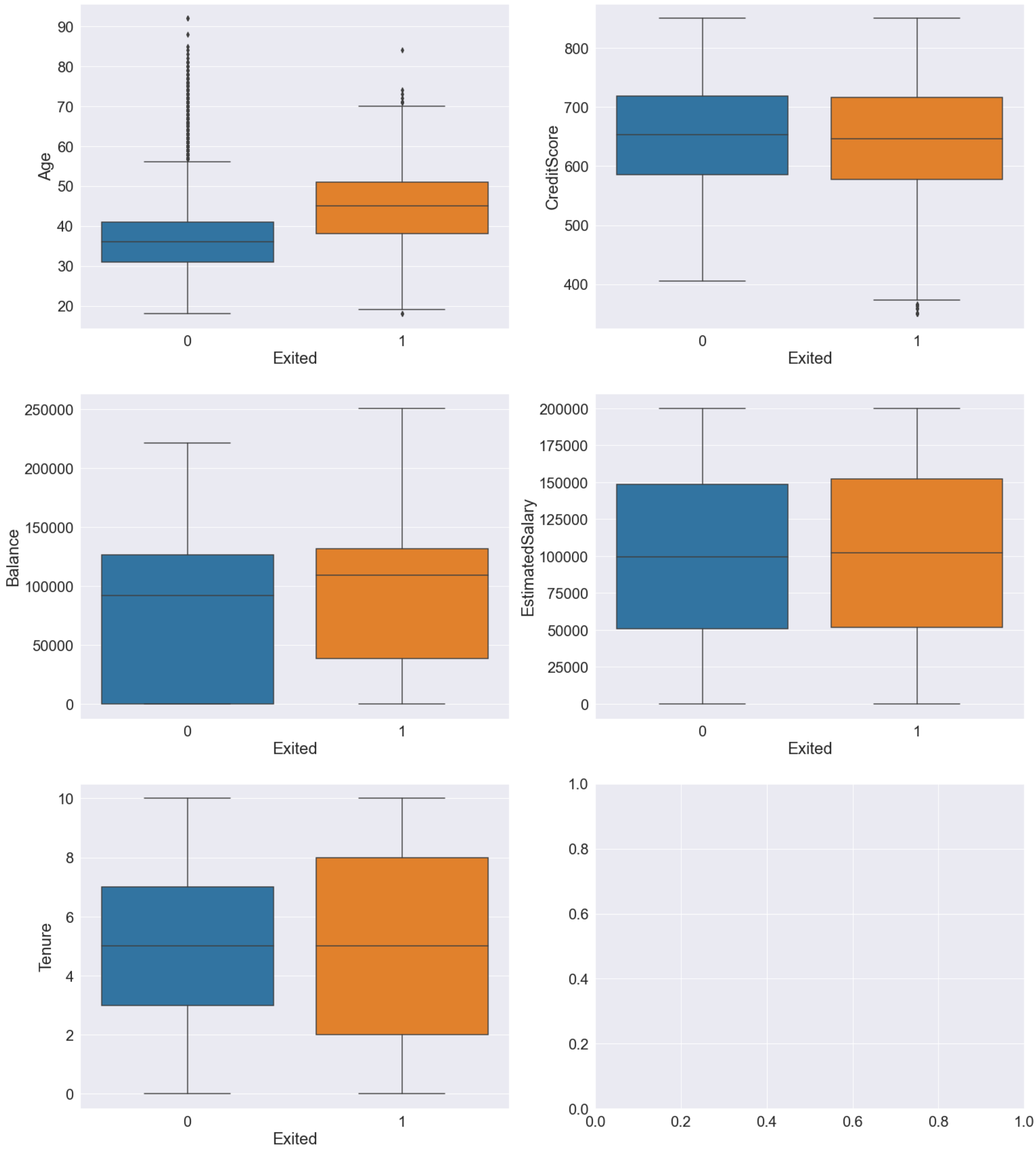
```
sns.set(rc={'figure.figsize':(25,15)})
sns.set(font_scale = 2)
fig,axs = plt.subplots(2,3)
sns.set_theme(palette="Paired")
sns.countplot(data = df,x = 'Gender',ax=axs[0,0])
sns.countplot(data = df,x = 'Geography',ax=axs[0,1])
```

```
sns.countplot(data = df,x = 'Tenure',ax=axs[0,2])
sns.countplot(data = df,x = 'NumOfProducts',ax=axs[1,0])
sns.countplot(data = df,x = 'HasCrCard',ax=axs[1,1])
sns.countplot(data = df,x = 'IsActiveMember',ax=axs[1,2])
plt.show()
```



In [14]:

```
sns.set(rc={'figure.figsize':(25,30)})
sns.set(font_scale = 2)
fig,axs = plt.subplots(3,2)
sns.set_theme(palette="tab10")
sns.boxplot(data = df,x = "Exited",y = "Age",ax = axs[0,0])
sns.boxplot(data = df,x = "Exited",y = "CreditScore",ax = axs[0,1])
sns.boxplot(data = df,x = "Exited",y = "Balance",ax = axs[1,0])
sns.boxplot(data = df,x = "Exited",y = "EstimatedSalary",ax = axs[1,1])
sns.boxplot(data = df,x = "Exited",y = "Tenure",ax=axs[2,0])
plt.show()
```



In [15]:

```
df[['Geography','Gender','Exited']].groupby(['Geography','Gender']).agg(['mean','cou
```

Out[15]:

		Exited	
		mean	**count**
Geography	**Gender**		
France	**Female**	0.203450	2261
	Male	0.127134	2753
Germany	**Female**	0.375524	1193
	Male	0.278116	1316
Spain	**Female**	0.212121	1089
	Male	0.131124	1388

In [16]:

```python
df['Exited'] = df['Exited'].astype('object')
```

In [17]:

```python
from sklearn.preprocessing import StandardScaler

ss = StandardScaler().fit_transform(df_num.values)

df_num = pd.DataFrame(data = ss,index = df_num.index,columns = df_num.columns)

df_num.describe()
```

Out[17]:

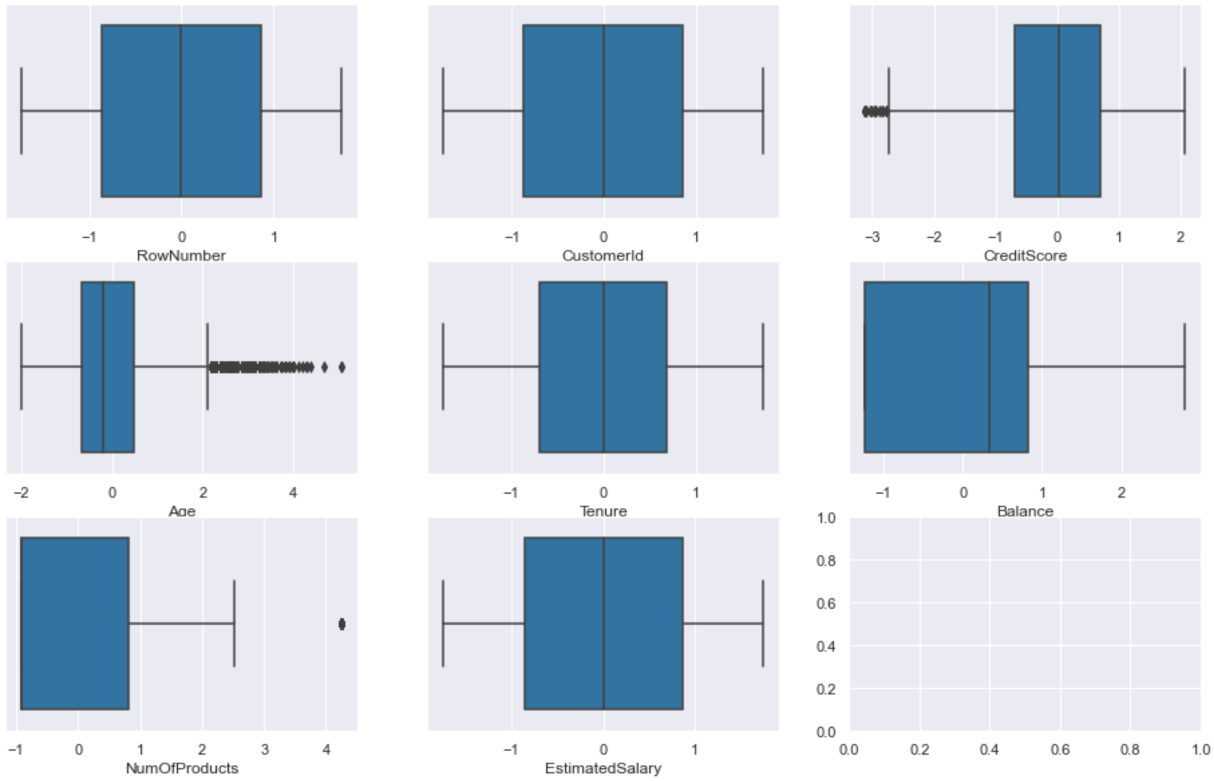
	RowNumber	CustomerId	CreditScore	Age	Tenure	Balance
count	1.000000e+04	1.000000e+04	1.000000e+04	1.000000e+04	1.000000e+04	1.000000e+04
mean	-2.338130e-17	7.588219e-15	-4.870326e-16	2.484679e-16	-1.400324e-16	-5.978551e-17
std	1.000050e+00	1.000050e+00	1.000050e+00	1.000050e+00	1.000050e+00	1.000050e+00
min	-1.731878e+00	-1.741069e+00	-3.109504e+00	-1.994969e+00	-1.733315e+00	-1.225848e+00
25%	-8.659388e-01	-8.676501e-01	-6.883586e-01	-6.600185e-01	-6.959818e-01	-1.225848e+00
50%	0.000000e+00	-2.816100e-03	1.522218e-02	-1.832505e-01	-4.425957e-03	3.319639e-01
75%	8.659388e-01	8.659939e-01	6.981094e-01	4.842246e-01	6.871299e-01	8.199205e-01
max	1.731878e+00	1.734255e+00	2.063884e+00	5.061197e+00	1.724464e+00	2.795323e+00

In [18]:

```python
#clean df

df = pd.concat([df_cat,df_num],axis = 1)
```

In [19]:

```python
fig,ax = plt.subplots(nrows = 3, ncols = 3, figsize = (16,10))

df_num = df.select_dtypes(np.number)
for i,j in zip(df_num.columns,ax.flatten()):
    sns.boxplot(df_num[i],ax = j)

plt.show()
```



In [20]:
```
q1 = df_num.quantile(0.25)
q3 = df_num.quantile(0.75)

iqr = q3 - q1

df = df[~((df < (q1 - 1.5 * iqr))| (df > (q3 + 1.5 * iqr))).any(axis = 1)]
df.shape
```

Out[20]:
```
(9515, 14)
```

In [21]:
```
df['Exited'].value_counts()/len(df)*100
```

Out[21]:
```
0    80.357331
1    19.642669
Name: Exited, dtype: float64
```

In [22]:
```
df = df.drop(['CustomerId','Surname','RowNumber'],axis = 1)
```

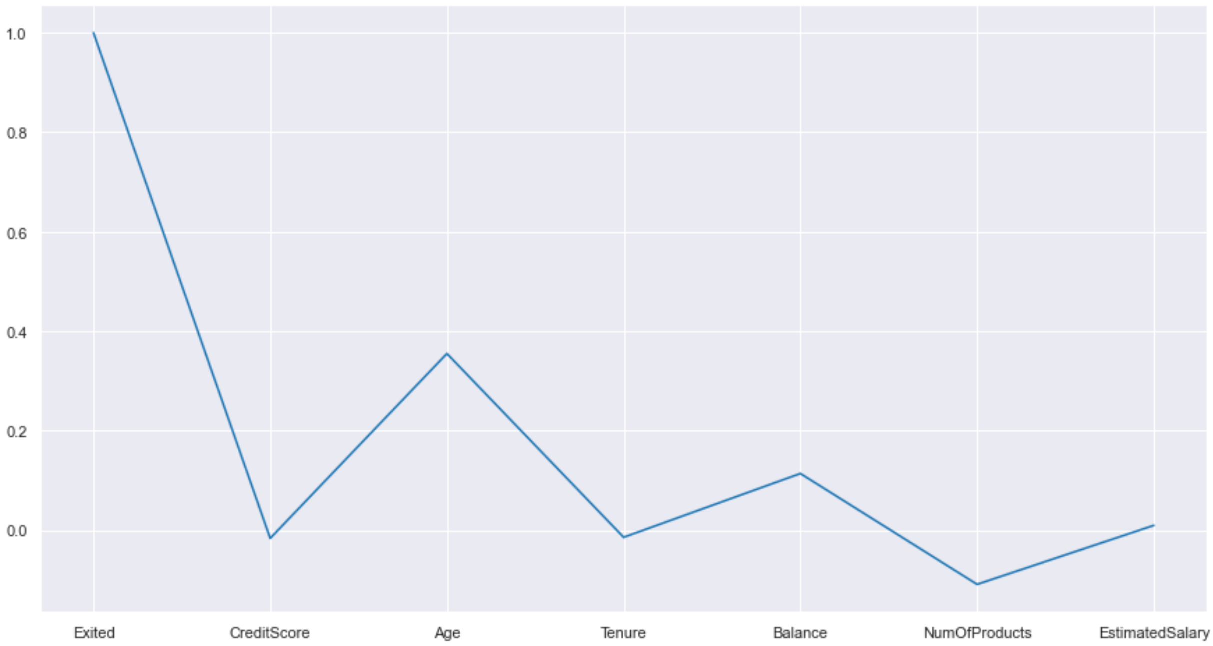
In [23]:
```
df['Exited'] = df['Exited'].astype('int')
```

In [24]:
```
plt.figure(figsize = (15,8))

sns.heatmap(df.corr(),annot = True)
```

Out[24]:
```
<AxesSubplot:>
```

In [25]:

```
plt.figure(figsize = (15,8))
df.corr()['Exited'].plot()
plt.show()
```



In [26]:

```
#Check for multi-collinearity using VIF

x = df.drop('Exited',axis = 1)

x = pd.get_dummies(x,drop_first = True)

y = df['Exited']

from statsmodels.stats.outliers_influence import variance_inflation_factor

vif = pd.DataFrame()

vif['vif_factor'] = [variance_inflation_factor(x.values,i) for i in range(x.shape[1]

vif['features'] = x.columns
```

```
multi = vif.sort_values('vif_factor',ascending = False).head()
multi
```

Out[26]:

	vif_factor	features
9	2.185012	HasCrCard_1
8	1.832480	Gender_Male
10	1.714972	IsActiveMember_1
6	1.580130	Geography_Germany
3	1.348576	Balance

In [27]:

```
multi = multi.features.to_list()
multi
```

Out[27]:

```
['HasCrCard_1',
 'Gender_Male',
 'IsActiveMember_1',
 'Geography_Germany',
 'Balance']
```

In [28]:

```
from sklearn.model_selection import train_test_split

x = df.drop('Exited',axis = 1)

x = pd.get_dummies(x,drop_first = True)
y = df['Exited']

x_train,x_test,y_train,y_test = train_test_split(x,y,test_size = 0.3,random_state =
```

In [29]:

```
from sklearn.tree import DecisionTreeClassifier
from sklearn.metrics import accuracy_score
```

In [30]:

```
dtc = DecisionTreeClassifier(random_state = 1)

model = dtc.fit(x_train,y_train)
```

In [31]:

```
print('The train accuracy is ',model.score(x_train,y_train))
print('The test accuracy is ',model.score(x_test,y_test))
```

```
The train accuracy is  1.0
The test accuracy is  0.8010507880910683
```

In [32]:

```
from sklearn.feature_selection import RFE
dtc = DecisionTreeClassifier(random_state = 1,class_weight = 'balanced')
rfe_model = RFE(estimator = dtc,n_features_to_select = 8)
rfe_model = rfe_model.fit(x_train,y_train)
```

In [33]:

```
df_rfe = pd.DataFrame()
df_rfe['features'] = x.columns
df_rfe['ranking'] = rfe_model.ranking_
```

```
top = df_rfe[df_rfe['ranking']==1]
top = top.features.to_list()
top
```

Out[33]:
```
['CreditScore',
 'Age',
 'Tenure',
 'Balance',
 'NumOfProducts',
 'EstimatedSalary',
 'Geography_Germany',
 'IsActiveMember_1']
```

In [34]:
```
x_top = x[top]


x_train,x_test,y_train,y_test = train_test_split(x_top,y,test_size = 0.3,random_stat

model_top = dtc.fit(x_train,y_train)
```

In [35]:
```
print('The train accuracy is ',model_top.score(x_train,y_train))
print('The test accuracy is ',model_top.score(x_test,y_test))
```

```
The train accuracy is  1.0
The test accuracy is  0.7950963222416813
```

In [36]:
```
from sklearn.model_selection import GridSearchCV

tuned_params = [{'criterion':['gini','entropy'],'max_depth': range(2,10),'min_sample

grid = GridSearchCV(estimator = dtc,param_grid = tuned_params,cv = 5)

grid.fit(x_train,y_train)
```

Out[36]:
```
GridSearchCV(cv=5,
             estimator=DecisionTreeClassifier(class_weight='balanced',
                                              random_state=1),
             param_grid=[{'criterion': ['gini', 'entropy'],
                          'max_depth': range(2, 10),
                          'min_samples_split': range(2, 10)}])
```

In [37]:
```
grid.best_params_
```

Out[37]:
```
{'criterion': 'gini', 'max_depth': 3, 'min_samples_split': 2}
```

In [38]:
```
dtc_tuned = DecisionTreeClassifier(random_state = 1,criterion = 'gini',max_depth = 3

model_final = dtc_tuned.fit(x_train,y_train)
```

In [39]:
```
print('The train accuracy is ',model_final.score(x_train,y_train))
print('The test accuracy is ',model_final.score(x_test,y_test))
```

```
The train accuracy is  0.8361861861861862
The test accuracy is  0.8329246935201401
```

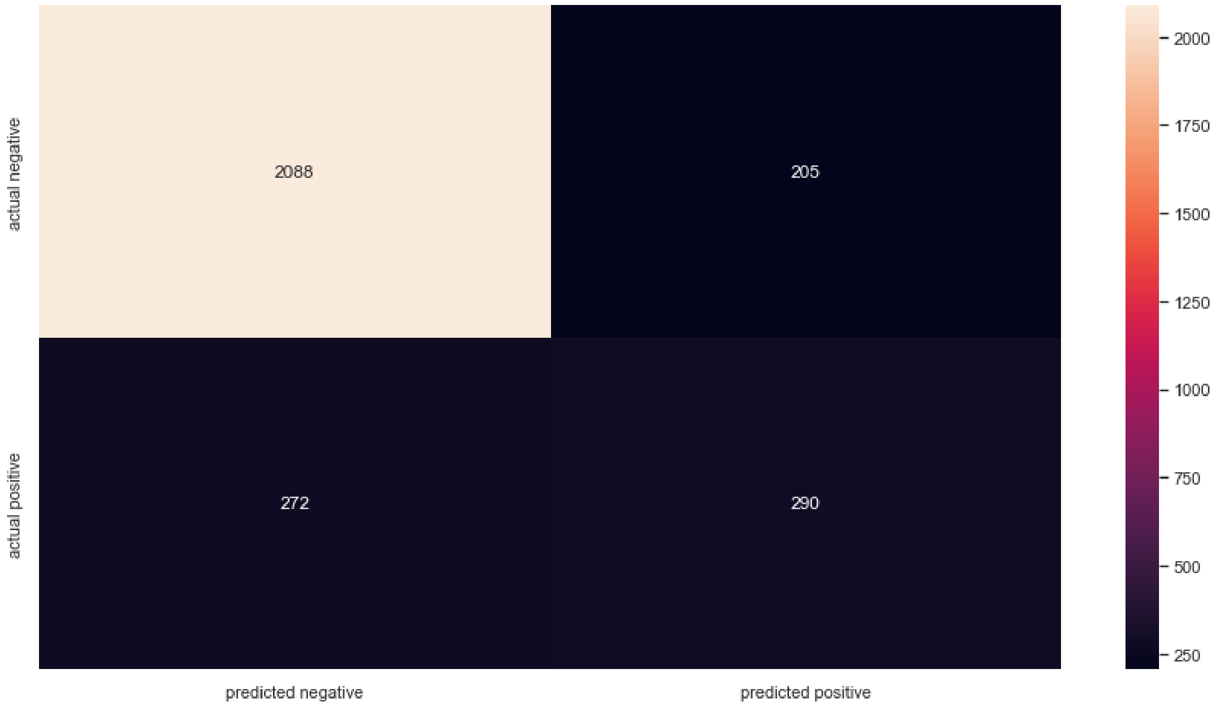
In [40]:
```
y_pred = model_final.predict(x_test)
```

```
from sklearn.metrics import classification_report

print(classification_report(y_test,y_pred))
```

```
              precision    recall  f1-score   support

           0       0.88      0.91      0.90      2293
           1       0.59      0.52      0.55       562

    accuracy                           0.83      2855
   macro avg       0.74      0.71      0.72      2855
weighted avg       0.83      0.83      0.83      2855
```

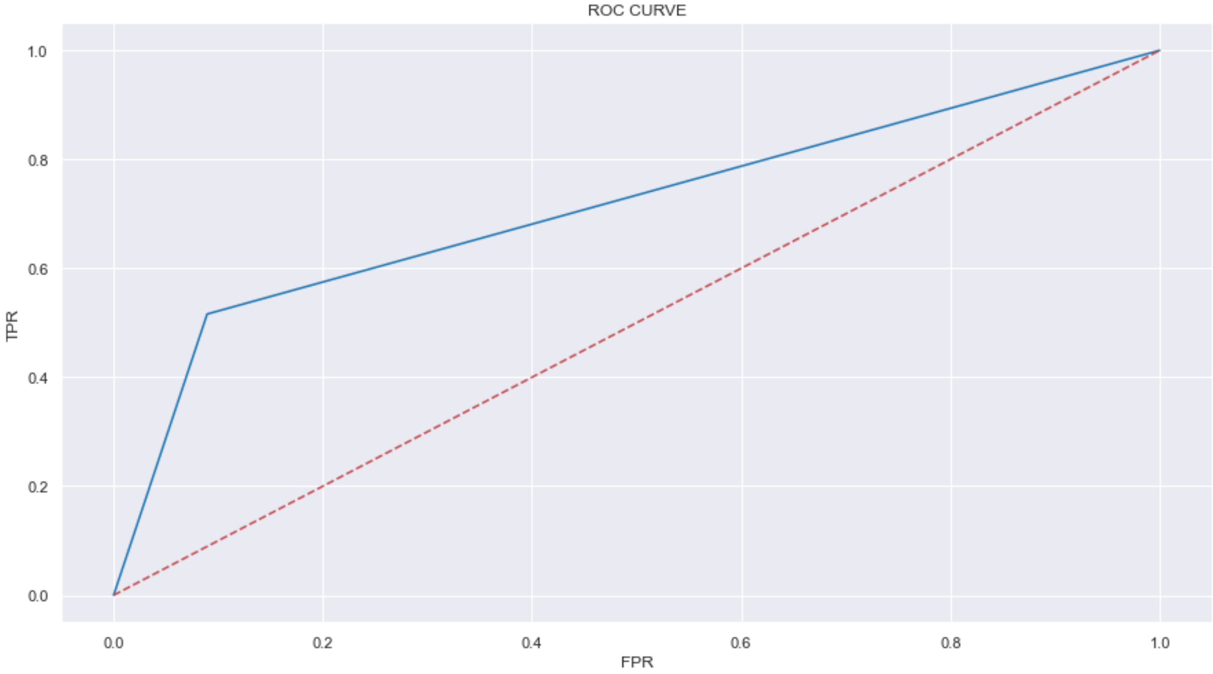
In [41]:

```
from sklearn.metrics import confusion_matrix
plt.figure(figsize = (15,8))
cm = confusion_matrix(y_test,y_pred)

conf = pd.DataFrame(data=cm,columns=['predicted negative','predicted positive'],inde
sns.heatmap(conf,annot=True,fmt='g')
plt.show()
```



In [42]:

```
from sklearn.metrics import roc_auc_score,roc_curve

y_pred = model_final.predict(x_test)

fpr,tpr,th = roc_curve(y_test,y_pred)
plt.figure(figsize = (15,8))
plt.plot(fpr,tpr,label = 'Decision Tree classifier')

plt.plot([0,1],[0,1],'r--')
plt.xlabel('FPR')
plt.ylabel('TPR')
plt.title('ROC CURVE')
plt.show()
```



In [43]:
```
print(roc_auc_score(y_test,y_pred))
```

```
0.7133058527190134
```

In [44]:
```
from sklearn.metrics import cohen_kappa_score

print(cohen_kappa_score(y_test,y_pred))
```

```
0.4467132941002009
```

In [45]:
```
#Random Forest Classifier

from sklearn.model_selection import train_test_split

x = df.drop('Exited',axis = 1)

x = pd.get_dummies(x,drop_first = True)
y = df['Exited']

x_train,x_test,y_train,y_test = train_test_split(x,y,test_size = 0.3,random_state =
```

In [46]:
```
from sklearn.ensemble import RandomForestClassifier

rf = RandomForestClassifier(random_state = 1,class_weight = 'balanced')

model_rf = rf.fit(x_train,y_train)
```

In [47]:
```
print('The train accuracy is ',model_rf.score(x_train,y_train))
print('The test accuracy is ',model_rf.score(x_test,y_test))
```

```
The train accuracy is  1.0
The test accuracy is  0.8591943957968476
```

In [48]:
```
from sklearn.feature_selection import RFE
rfc = RandomForestClassifier(random_state = 1,class_weight = 'balanced')
rfe_model = RFE(estimator = rfc,n_features_to_select = 8)
rfe_model = rfe_model.fit(x_train,y_train)
```

In [49]:
```
df_rfe = pd.DataFrame()
df_rfe['features'] = x.columns
df_rfe['ranking'] = rfe_model.ranking_

top = df_rfe[df_rfe['ranking']==1]
top = top.features.to_list()
top
```

Out[49]:
```
['CreditScore',
 'Age',
 'Tenure',
 'Balance',
 'NumOfProducts',
 'EstimatedSalary',
 'Geography_Germany',
 'IsActiveMember_1']
```

In [50]:
```
x_top = x[top]


x_train,x_test,y_train,y_test = train_test_split(x_top,y,test_size = 0.3,random_stat

model_rf_top = dtc.fit(x_train,y_train)
```

In [51]:
```
print('The train accuracy is ',model_rf_top.score(x_train,y_train))
print('The test accuracy is ',model_rf_top.score(x_test,y_test))
```

```
The train accuracy is  1.0
The test accuracy is  0.7950963222416813
```

In [52]:
```
params =  {'max_depth': range(2,10)}

grid = GridSearchCV(estimator = rf, param_grid = params,cv = 5)

grid.fit(x_train, y_train)
```

Out[52]:
```
GridSearchCV(cv=5,
             estimator=RandomForestClassifier(class_weight='balanced',
                                              random_state=1),
             param_grid={'max_depth': range(2, 10)})
```

In [53]:
```
grid.best_params_
```

Out[53]:
```
{'max_depth': 9}
```

In [54]:
```
rf_tuned = RandomForestClassifier(random_state = 1,max_depth =9)

model_rf = rf_tuned.fit(x_train,y_train)
```

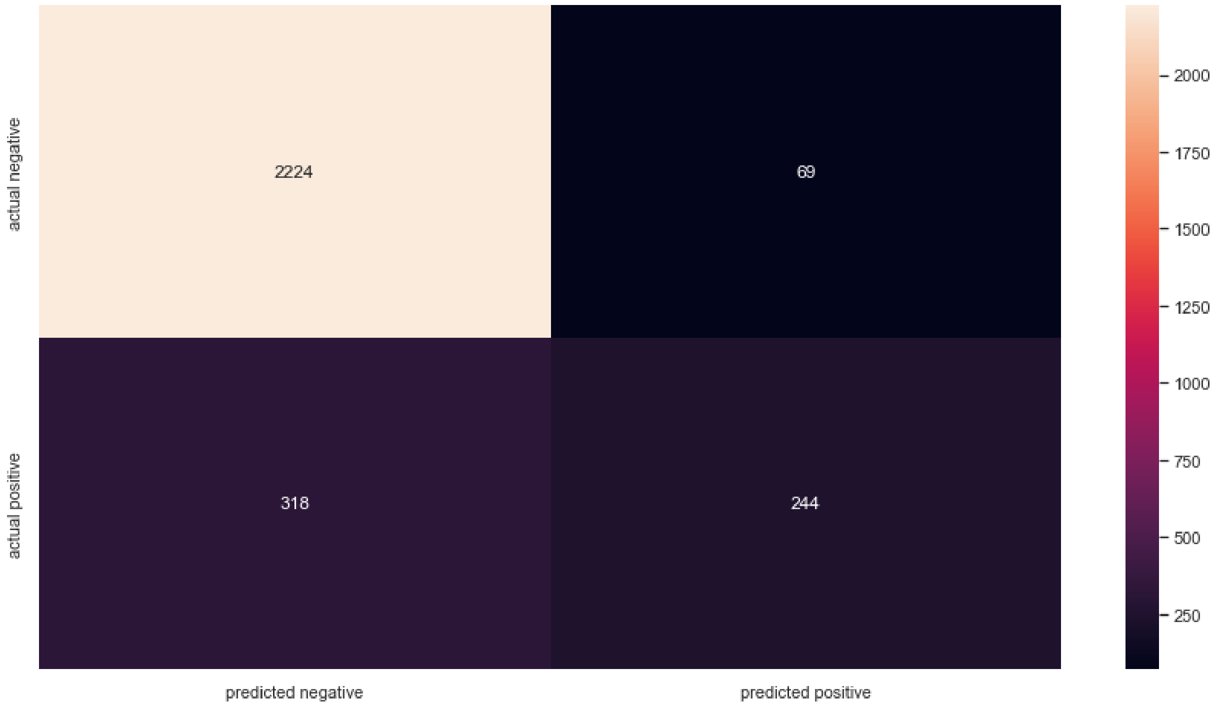
In [55]:
```
print('The train accuracy is ',model_rf.score(x_train,y_train))
print('The test accuracy is ',model_rf.score(x_test,y_test))
```

```
The train accuracy is  0.8924924924924925
The test accuracy is  0.8644483362521891
```

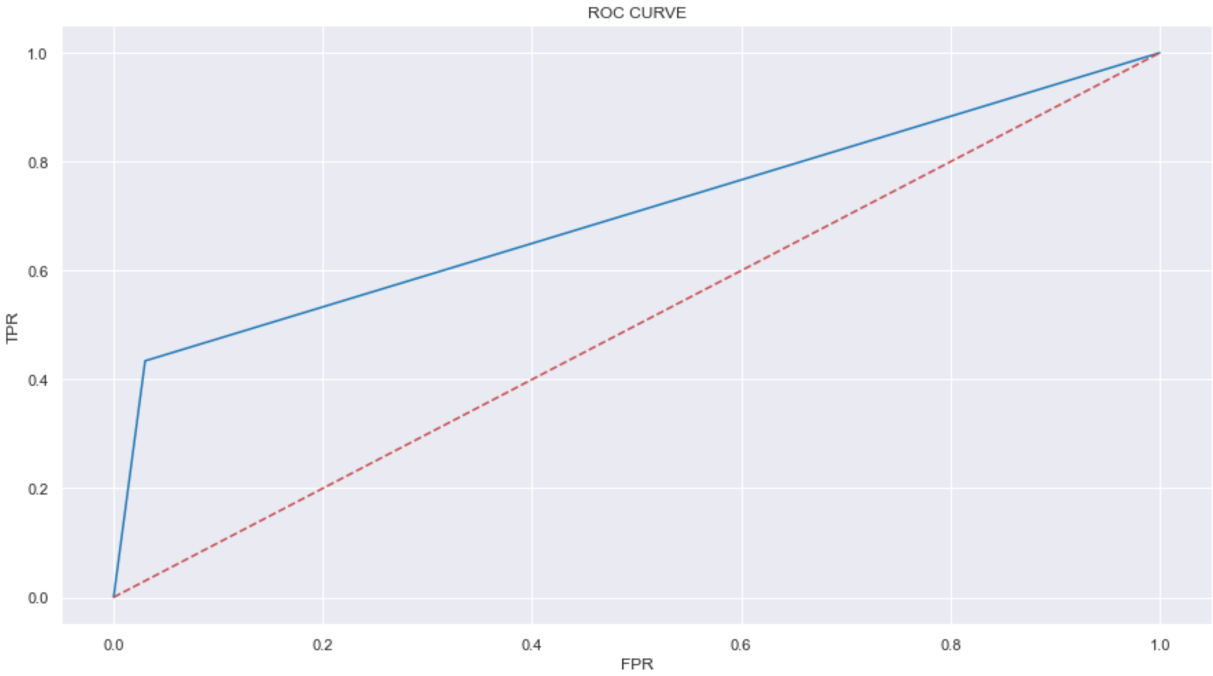
In [56]:
```
y_pred_rf = model_rf.predict(x_test)

from sklearn.metrics import classification_report

print(classification_report(y_test,y_pred_rf))
```

```
              precision    recall  f1-score   support

           0       0.87      0.97      0.92      2293
           1       0.78      0.43      0.56       562

    accuracy                           0.86      2855
   macro avg       0.83      0.70      0.74      2855
weighted avg       0.86      0.86      0.85      2855
```

In [57]:
```
from sklearn.metrics import confusion_matrix

cm = confusion_matrix(y_test,y_pred_rf)

plt.figure(figsize = (15,8))

conf = pd.DataFrame(data=cm,columns=['predicted negative','predicted positive'],inde
sns.heatmap(conf,annot=True,fmt='g')
plt.show()
```



In [58]:
```
fpr,tpr,th = roc_curve(y_test,y_pred_rf)
plt.figure(figsize = (15,8))
plt.plot(fpr,tpr,label = 'Random Forest Classifier')

plt.plot([0,1],[0,1],'r--')
plt.xlabel('FPR')
plt.ylabel('TPR')
plt.title('ROC CURVE')
plt.show()
```



In [59]:
```
print(roc_auc_score(y_test,y_pred_rf))
```

```
0.7020360589943399
```

In [60]:
```
print(cohen_kappa_score(y_test,y_pred_rf))
```

```
0.48521720736910234
```

In [61]:
```
from sklearn.model_selection import train_test_split

x = df.drop('Exited',axis = 1)

x = pd.get_dummies(x,drop_first = True)
y = df['Exited']

x_train,x_test,y_train,y_test = train_test_split(x,y,test_size = 0.3,random_state =
```

In [62]:
```
from sklearn.linear_model import LogisticRegression

lr = LogisticRegression(random_state = 1,C = 0.01,penalty='l2',class_weight = 'balan

model_lr = lr.fit(x_train,y_train)
```

In [63]:
```
print('The train accuracy is ',model_lr.score(x_train,y_train))
print('The test accuracy is ',model_lr.score(x_test,y_test))
```

```
The train accuracy is  0.7273273273273273
The test accuracy is  0.7260945709281962
```

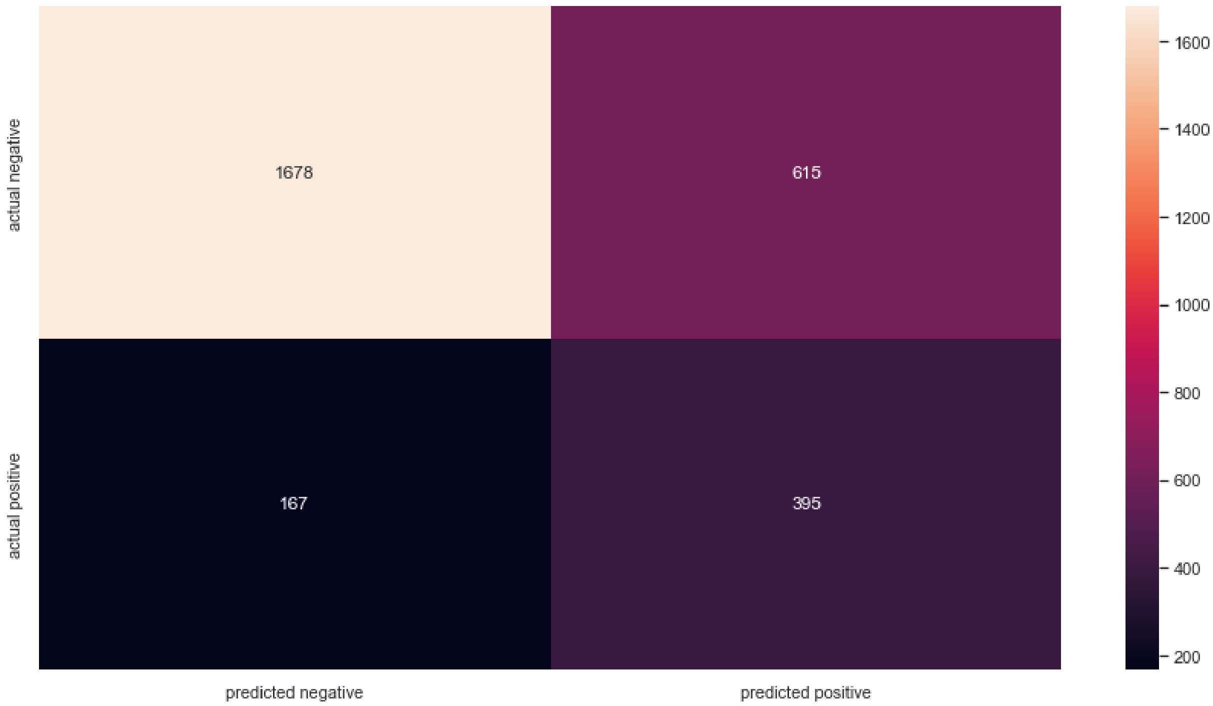
In [64]:
```
y_pred_lr = model_lr.predict(x_test)
```

In [65]:
```
from sklearn.metrics import classification_report

print(classification_report(y_test,y_pred_lr))
```

```
              precision    recall  f1-score   support

           0       0.91      0.73      0.81      2293
           1       0.39      0.70      0.50       562

    accuracy                           0.73      2855
   macro avg       0.65      0.72      0.66      2855
weighted avg       0.81      0.73      0.75      2855
```

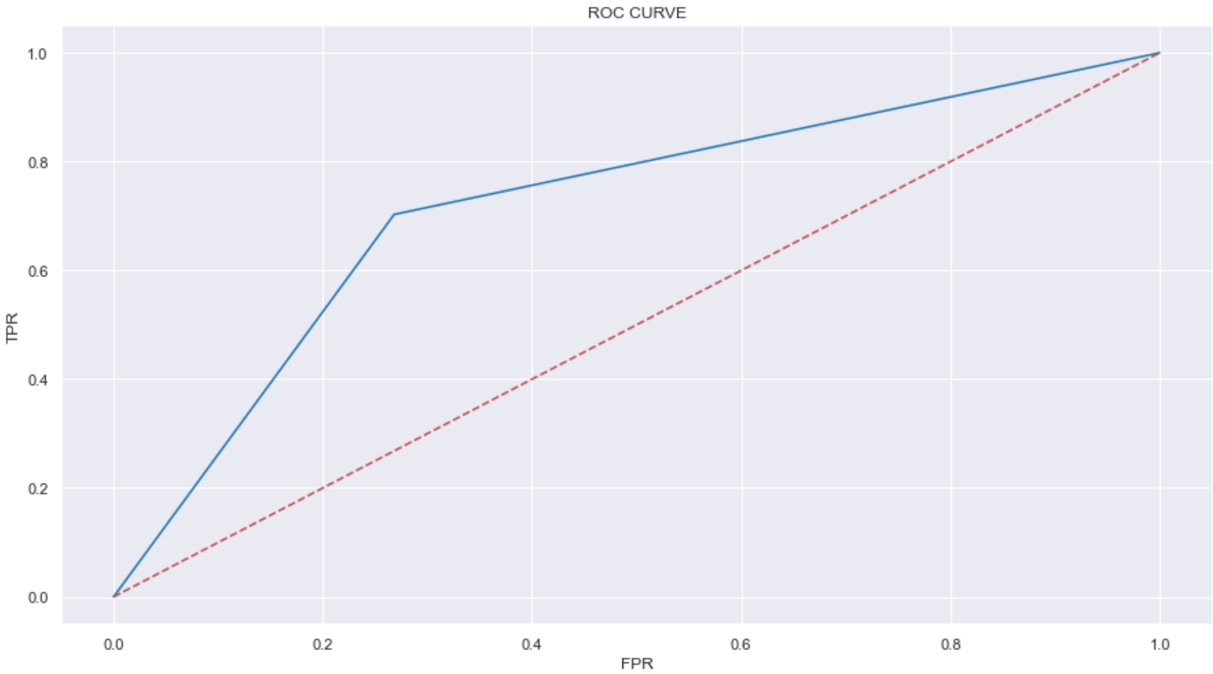
In [66]:

```
from sklearn.metrics import confusion_matrix

cm = confusion_matrix(y_test,y_pred_lr)

plt.figure(figsize = (15,8))

conf = pd.DataFrame(data=cm,columns=['predicted negative','predicted positive'],inde
sns.heatmap(conf,annot=True,fmt='g')
plt.show()
```



In [67]:

```
fpr,tpr,th = roc_curve(y_test,y_pred_lr)
plt.figure(figsize = (15,8))
plt.plot(fpr,tpr,label = 'Logistic Regression')

plt.plot([0,1],[0,1],'r--')
plt.xlabel('FPR')
plt.ylabel('TPR')
plt.title('ROC CURVE')
plt.show()
```



In [68]:

```
print(roc_auc_score(y_test,y_pred_lr))
```

```
0.7173196933883567
```

In [69]:

```
print(cohen_kappa_score(y_test,y_pred_lr))
```

```
0.33410979414343744
```

In [70]:

```
comparison = pd.DataFrame(data = [['Decision Tree Classifier',83,290,2088,205,272,0.
                                  ['Random Forest classifier',86,244,2224,69,318,0.7
                          columns = ['Algorithm Name','Accuracy','True Positive','Tr

comparison
```

Out[70]:

	Algorithm Name	Accuracy	True Positive	True Negative	False Positive	False Negative	ROC-AUC Score	Cohen-Kappa Score
0	Decision Tree Classifier	83	290	2088	205	272	0.71	0.44
1	Logistic Regression	72	395	1678	615	167	0.71	0.33
2	Random Forest classifier	86	244	2224	69	318	0.70	0.48