Deep Learning Project - Bank Customer Churning

A bank is investigating a very high rate of customers leaving the bank.The dataset contain 10,000 records from which we need to investigate and predict which of the customers are more likely to leave the bank soon.

In [1]:
```python
# Basic Imports
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns

import tensorflow as tf

# Skewness
from scipy.stats import skew

# TrainTestSplit
from sklearn.model_selection import train_test_split

# Preprocessing - StandardScaler, LabelEncoder
from sklearn.preprocessing import StandardScaler, LabelEncoder

# ClassificationReport
from sklearn.metrics import classification_report

# OverSampling
from imblearn.over_sampling import RandomOverSampler, SMOTE
from imblearn.under_sampling import RandomUnderSampler
from collections import Counter

# ConfusionMatrix
from sklearn.metrics import confusion_matrix

# AUC ROC
from sklearn.metrics import roc_auc_score, roc_curve

# Warnings
import warnings
warnings.filterwarnings("ignore")
```

In [2]:
```python
df = pd.read_csv("Churn_Modelling.csv")
```

In [3]:
```python
df.shape
```

Out[3]: (10000, 14)

In [4]:
```python
df.head()
```

Out[4]:

	RowNumber	CustomerId	Surname	CreditScore	Geography	Gender	Age	Tenure	Balance	Num
0	1	15634602	Hargrave	619	France	Female	42	2	0.00	

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

In [5]: `df.info()`

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 14 columns):
 #   Column           Non-Null Count  Dtype
---  ------           --------------  -----
 0   RowNumber        10000 non-null  int64
 1   CustomerId       10000 non-null  int64
 2   Surname          10000 non-null  object
 3   CreditScore      10000 non-null  int64
 4   Geography        10000 non-null  object
 5   Gender           10000 non-null  object
 6   Age              10000 non-null  int64
 7   Tenure           10000 non-null  int64
 8   Balance          10000 non-null  float64
 9   NumOfProducts    10000 non-null  int64
 10  HasCrCard        10000 non-null  int64
 11  IsActiveMember   10000 non-null  int64
 12  EstimatedSalary  10000 non-null  float64
 13  Exited           10000 non-null  int64
dtypes: float64(2), int64(9), object(3)
memory usage: 1.1+ MB
```

This dataset does not have any NaN values, and no updated need to be performed on the Dtypes for any of the features.

In [6]: `df.nunique()`

Out[6]:
```
RowNumber          10000
CustomerId         10000
Surname             2932
CreditScore          460
Geography              3
Gender                 2
Age                   70
Tenure                11
Balance             6382
NumOfProducts          4
HasCrCard              2
IsActiveMember         2
EstimatedSalary     9999
Exited                 2
dtype: int64
```

From the above information, we can look to drop 'RowNumber', 'CustomerId' and 'Surname'. 'RowNumber' and 'CustomerId' contain all unqiue values, with the latter only used for customer identification. 'CustomerId' might be linked to another database that would have complete personal details of the customer.

Also, It is highly unlikely that people with particular surnames may or may not influence their

decision on staying or exiting. And here too it is likely that the data under 'Surname' might be linked to another dataset.

In [7]:
```python
df.drop(["RowNumber", "CustomerId", "Surname"], axis=1, inplace=True)
```

Separating catergorical and numerical features.

In [8]:
```python
df_cat = df[["Geography", "Gender", "NumOfProducts", "HasCrCard", "IsActiveMember", "Te
df_num = df.drop(df_cat, axis=1)
df_num.drop("Exited", axis=1, inplace=True)
```

In [9]:
```python
df_cat.head()
```

Out[9]:

	Geography	Gender	NumOfProducts	HasCrCard	IsActiveMember	Tenure
0	France	Female	1	1	1	2
1	Spain	Female	1	0	1	1
2	France	Female	3	1	0	8
3	France	Female	2	0	0	1
4	Spain	Female	1	1	1	2

In [10]:
```python
df_num.head()
```

Out[10]:

	CreditScore	Age	Balance	EstimatedSalary
0	619	42	0.00	101348.88
1	608	41	83807.86	112542.58
2	502	42	159660.80	113931.57
3	699	39	0.00	93826.63
4	850	43	125510.82	79084.10

Feature - *Exited*

In [11]:
```python
(df["Exited"].value_counts()*100) / len(df)
```

Out[11]:
```
0    79.63
1    20.37
Name: Exited, dtype: float64
```

In [12]:
```python
plt.figure(figsize=(7,7))
plt.pie(x=((df["Exited"].value_counts()*100) / len(df)), labels=['Member', 'Exited'], e
plt.title("Customer Status")
plt.show()
```

Customer Status
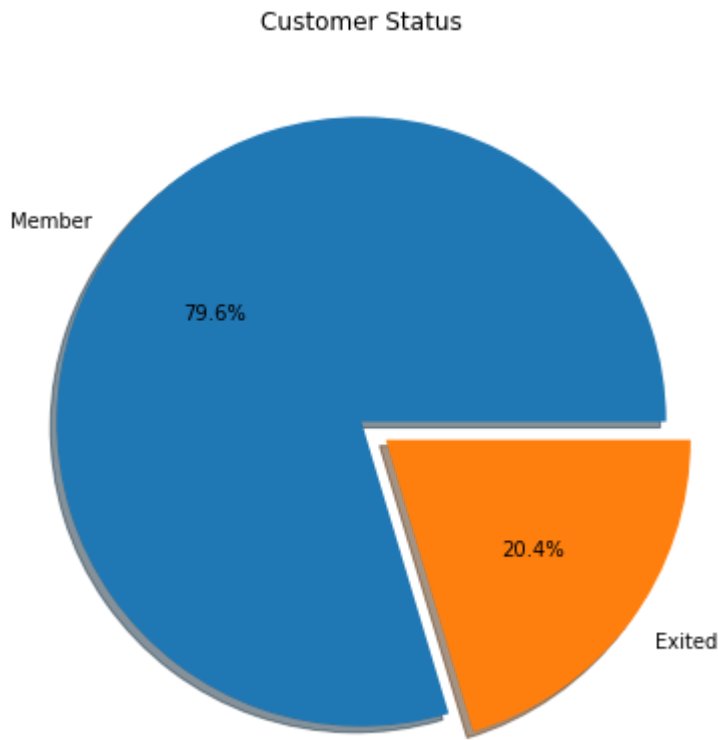
The above pie chart shows us the percentage of existing customers and those who have exited.
We would need to perform sampling on the data as the ratio of 1-to-0 is 1:4.
We will create a function that will allow us to create a model with and without sampling.

Feature - *IsActiveMember*

```
In [13]:  df["IsActiveMember"].value_counts()
```

```
Out[13]:  1    5151
          0    4849
          Name: IsActiveMember, dtype: int64
```

```
In [14]:  df[df["IsActiveMember"] == 0].head(6)
```

Out[14]:

	CreditScore	Geography	Gender	Age	Tenure	Balance	NumOfProducts	HasCrCard	IsActiveMe
2	502	France	Female	42	8	159660.80	3	1	
3	699	France	Female	39	1	0.00	2	0	
5	645	Spain	Male	44	8	113755.78	2	1	
7	376	Germany	Female	29	4	115046.74	4	1	
10	528	France	Male	31	6	102016.72	2	0	
11	497	Spain	Male	24	3	0.00	2	1	

```
In [15]:  df[df["IsActiveMember"] == 1].head(6)
```

Out[15]:

	CreditScore	Geography	Gender	Age	Tenure	Balance	NumOfProducts	HasCrCard	IsActiveMem
0	619	France	Female	42	2	0.00	1	1	
1	608	Spain	Female	41	1	83807.86	1	0	
4	850	Spain	Female	43	2	125510.82	1	1	
6	822	France	Male	50	7	0.00	2	1	
8	501	France	Male	44	4	142051.07	2	0	
9	684	France	Male	27	2	134603.88	1	1	

In [16]:
```python
plt.figure(figsize=(7,7))
plt.pie(x=((df["IsActiveMember"].value_counts()*100) / len(df)), labels=['Active Custom
plt.title("Customer Activity")
plt.show()
```
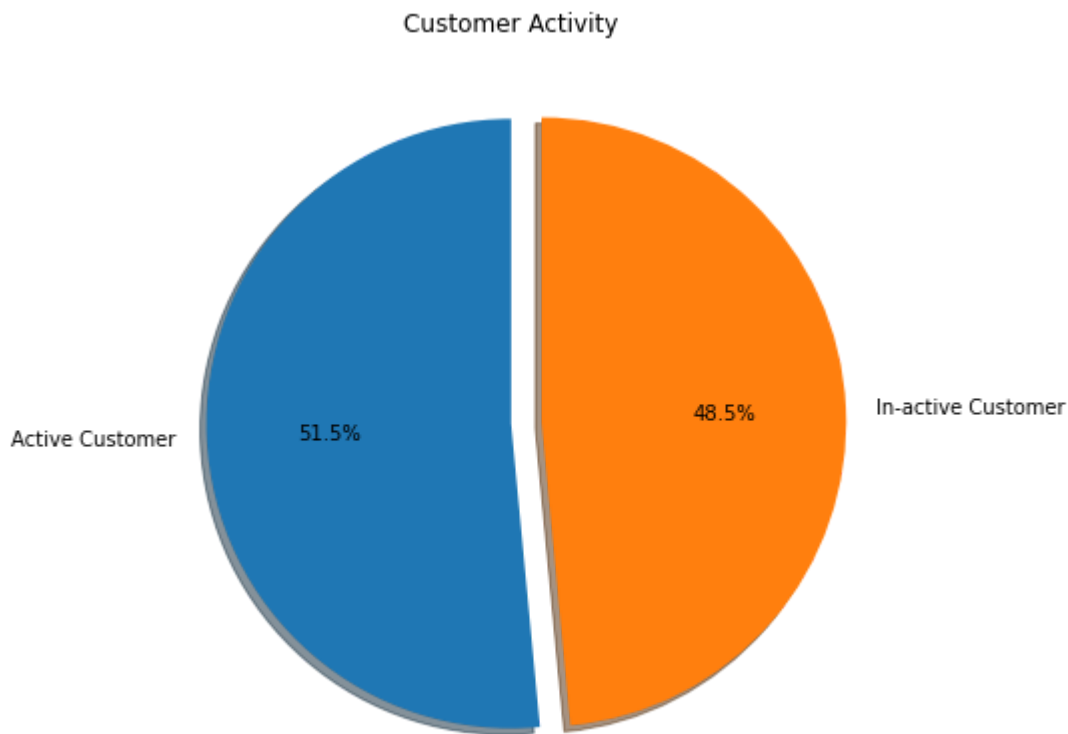
Customer Activity

The dataset also contains a feature that indicates the number of active and inactive members. It is not clear as to what this signifies about the customer.

- Could it mean that their account is now inactive as there has been no sort of activity (deposits/withdrawls/transfer between accounts) for a while?
- Or could it mean that the customer has signed up for some membership plan offered by the bank?

In [17]:
```python
plt.figure(figsize=(15,15))
ax1 = plt.subplot2grid((1,2), (0, 0))
plt.pie(x=df[df["IsActiveMember"] == 1]["Exited"].value_counts(), labels=['Not Exited',
plt.title("Active Customer")
```

```
ax2 = plt.subplot2grid((1,2), (0, 1))
plt.pie(x=df[df["IsActiveMember"] == 0]["Exited"].value_counts(), labels=['Not Exited',
plt.title("Inactive Customer")
plt.show()
```

Active Customer   Inactive Customer

Exited   Exited

14.3%   26.9%

73.1%

85.7%

Not Exited   Not Exited
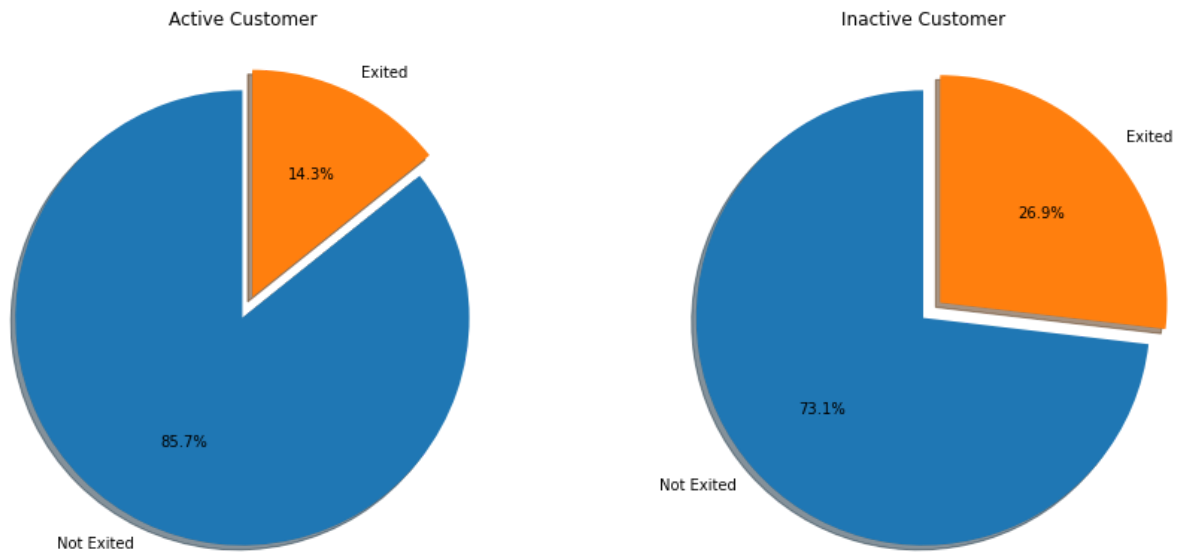
The above two graphs show us the percentage of customers who have exited and who are still with the bank from the 'IsActiveMember' feature.

Numerical Features Distribution

In [18]:
```
fig, ax_plot = plt.subplots(nrows=2, ncols=2, figsize=(15,12))
sns.distplot(df["CreditScore"], ax=ax_plot[0][0])
sns.distplot(df["Age"], ax=ax_plot[0][1])
sns.distplot(df["Balance"], ax=ax_plot[1][0])
sns.distplot(df["EstimatedSalary"], ax=ax_plot[1][1])
plt.show()

for each in df_num:
    print("{:<15} : {}" .format(each, skew(df[each])))
```
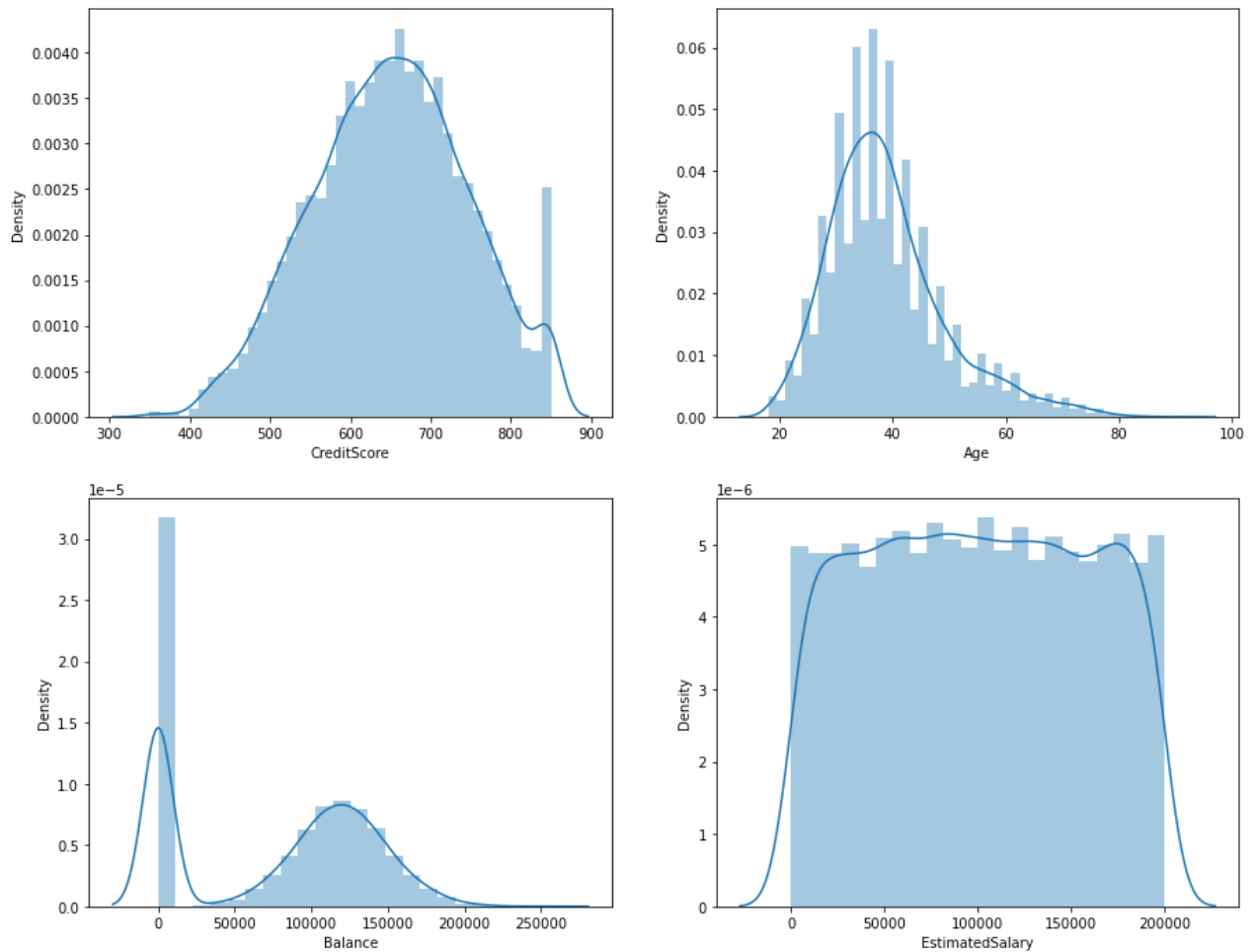
```
CreditScore      : -0.07159586676212397
Age              : 1.0111685586628079
Balance          : -0.14108754375291138
EstimatedSalary  : 0.0020850448448748848
```

There is some skewness in 'Balance', while 'Age' is skewed, but not very high. We can work with on this after creating the base model.

Numerical Features Summarization

```
In [19]:  fig, ax_plot = plt.subplots(nrows=2, ncols=2, figsize=(15,13))
          sns.boxplot(y='CreditScore', x='Exited', hue='Exited',data=df, ax=ax_plot[0][0])
          sns.boxplot(y='Age', x='Exited', hue='Exited',data=df, ax=ax_plot[0][1])
          sns.boxplot(y='Balance', x='Exited', hue='Exited',data=df, ax=ax_plot[1][0])
          sns.boxplot(y='EstimatedSalary', x='Exited', hue='Exited',data=df, ax=ax_plot[1][1])
          plt.show()
```
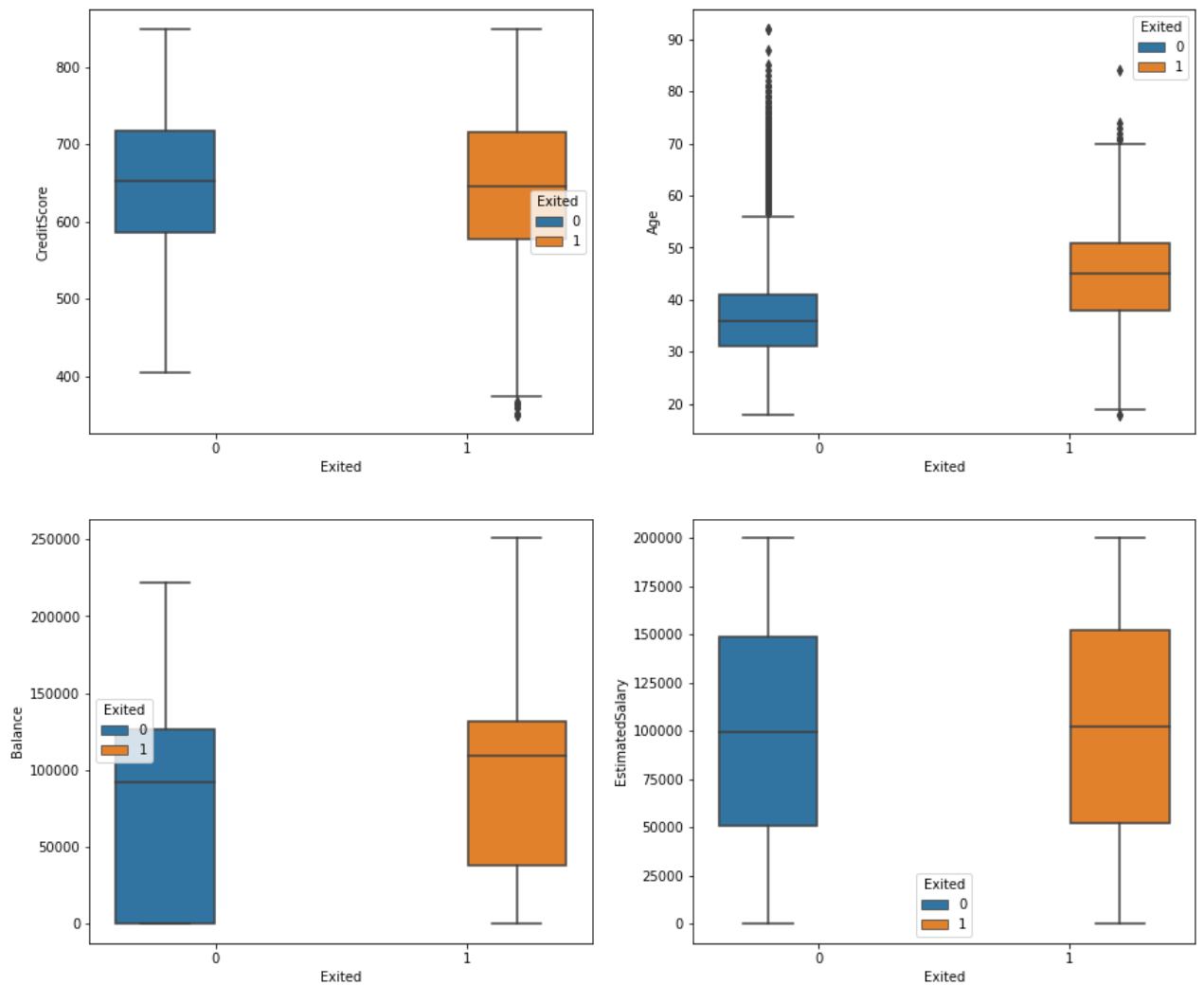
Assumptions

'Age' And 'Balance'

They do seem to influence whether a customer might exit or not. There is a bit of variance in the data of these two features, including the median.

'CreditScore' and 'EstimatedSalary'

These features do not seem to have much influence over a customer exiting or not. The distribution for both seem to be normal, with some outliers in 'CreditScore'.

Categorical Features

```
In [20]:   fig, ax_plot = plt.subplots(nrows=3, ncols=2, figsize=(15,13))
           sns.countplot(x='Geography', hue='Exited',data=df, ax=ax_plot[0][0])
           sns.countplot(x='Gender', hue='Exited',data=df, ax=ax_plot[1][0])
           sns.countplot(x='HasCrCard', hue='Exited',data=df, ax=ax_plot[0][1])
           sns.countplot(x='IsActiveMember', hue='Exited',data=df, ax=ax_plot[1][1])
           sns.countplot(x='Tenure', hue='Exited',data=df, ax=ax_plot[2][0])
           plt.show()
```
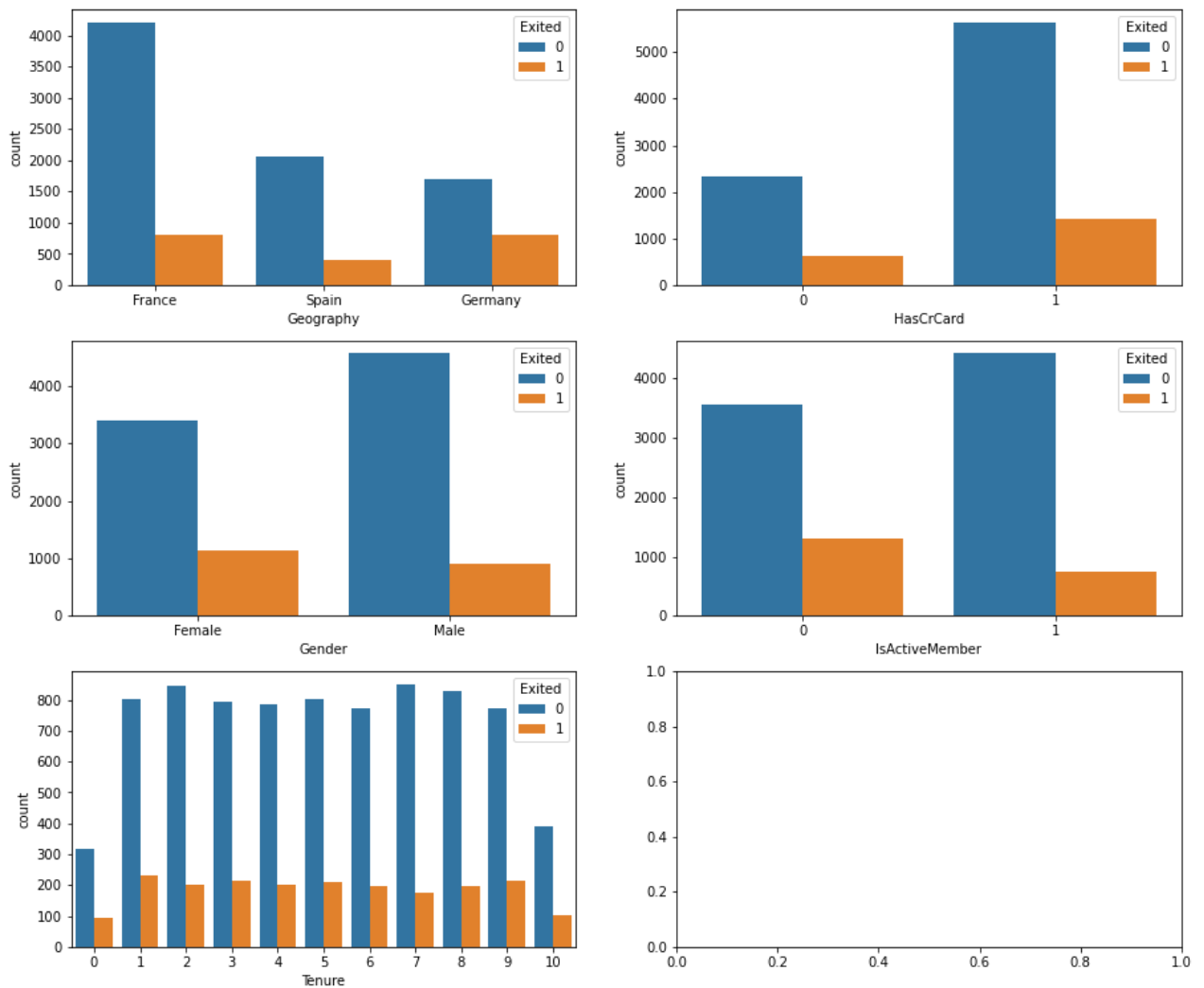
Assumptions

Geography

**Most of the bank customers are from France. And most of the French customers are still existing customers.
The country with the lowest number of customers who have left is Spain.**

Credit Card Holder

A lot of the customers have credit cards. However, it would seem that this does not influence a customer to stay or exit.

Gender

Overall, there are more Male customers. But the percentage of Female customers having exited is slightly more.

Active Customer

From the total number of inactive customers, less than 50% of them had exited. From the existing active customers, and a lot of them have not exited. However, there are some active

customers who have left the bank. Would this soon make them inactive?

Features - *'EstimatedSalary'* & *'Balance'*

In [21]:
```python
groups = ["Low", "Medium", "High"]

df["EstimatedSalary_Range"] = pd.qcut(df["EstimatedSalary"], q=3, labels=groups)
df[["EstimatedSalary", "EstimatedSalary_Range"]].head(10)
```

Out[21]:

	EstimatedSalary	EstimatedSalary_Range
0	101348.88	Medium
1	112542.58	Medium
2	113931.57	Medium
3	93826.63	Medium
4	79084.10	Medium
5	149756.71	High
6	10062.80	Low
7	119346.88	Medium
8	74940.50	Medium
9	71725.73	Medium

In [22]:
```python
df["Balance_Range"] = pd.qcut(df["Balance"], q=[.0,.5,.75,1.], labels=groups, duplicate
df[["Balance", "Balance_Range"]].head(10)
```

Out[22]:

	Balance	Balance_Range
0	0.00	Low
1	83807.86	Low
2	159660.80	High
3	0.00	Low
4	125510.82	Medium
5	113755.78	Medium
6	0.00	Low
7	115046.74	Medium
8	142051.07	High
9	134603.88	High

In [23]:
```python
df["EstimatedSalary_Range"].value_counts()
```

Out[23]:
```
Low     3334
High    3333
```

```
       Medium     3333
       Name: EstimatedSalary_Range, dtype: int64
```

In [24]:
```
df["Balance_Range"].value_counts()
```

Out[24]:
```
Low        5000
High       2500
Medium     2500
Name: Balance_Range, dtype: int64
```

In [25]:
```
plt.subplots(figsize=(15,15))
plt.subplot2grid((1,2), (0,0))
plt.pie(x=df["EstimatedSalary_Range"].value_counts(), autopct='%1.1f%%', explode=(0.1,0
plt.title("Estimated Salary Range")
plt.subplot2grid((1,2), (0,1))
plt.pie(x=df["Balance_Range"].value_counts(), autopct='%1.1f%%', explode=(0.1,0.1,0.1),
plt.title("Balance Range")
plt.show()
```
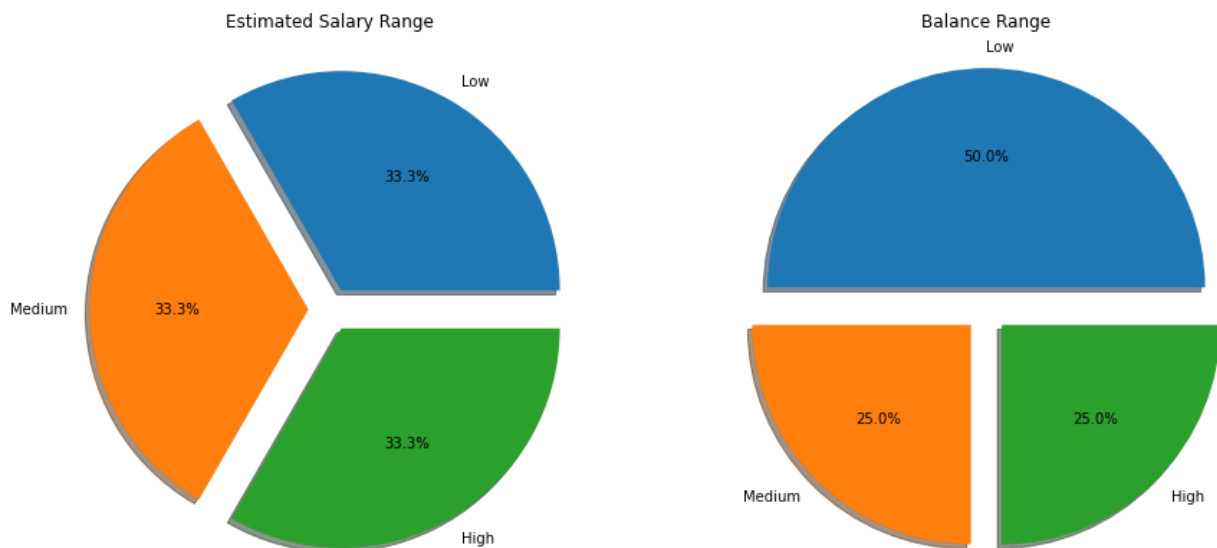

In [26]:
```
len(df[df["Balance"] == 0])
```

Out[26]: **3617**

In [27]:
```
df["Exited"][df["Balance"] == 0].value_counts()
```

Out[27]:
```
0    3117
1     500
Name: Exited, dtype: int64
```

In [28]:
```
plt.figure(figsize=(7,7))
plt.pie(df["Exited"][df["Balance"] == 0].value_counts(), explode=(0,0.1), shadow=True,
plt.title("Churned Customers (Based on Zero Balance)")
plt.show()
```

Churned Customers (Based on Zero Balance)
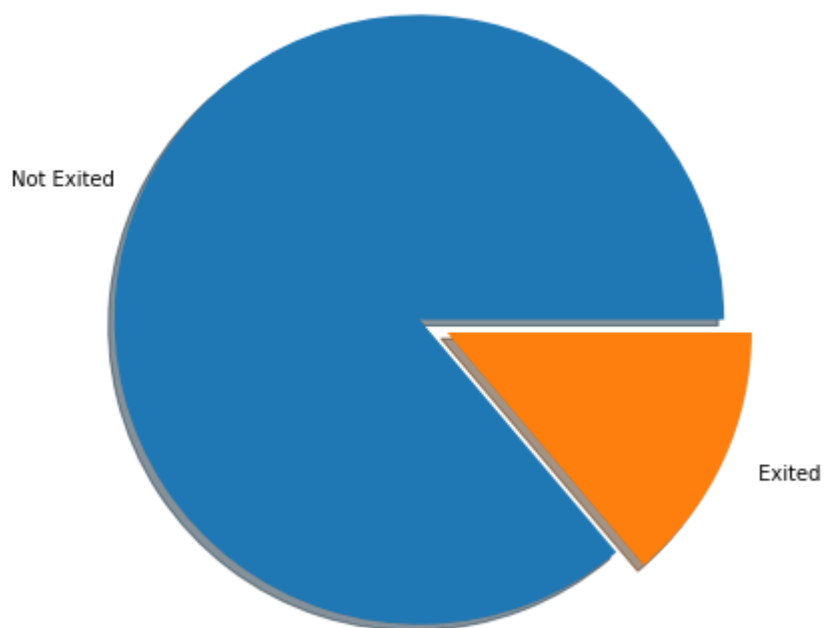

```
In [29]:  print(df[df["Balance"] > 0]["Balance_Range"].value_counts())
          print()

          plt.figure(figsize=(7,7))
          plt.pie(df[df["Balance"] > 0]["Balance_Range"].value_counts(), explode=((0.1),(0.1),(0.
          plt.title("Balance Range while excluding Zero Balance")
          plt.show()
```

```
High      2500
Medium    2500
Low       1383
Name: Balance_Range, dtype: int64
```

Balance Range while excluding Zero Balance
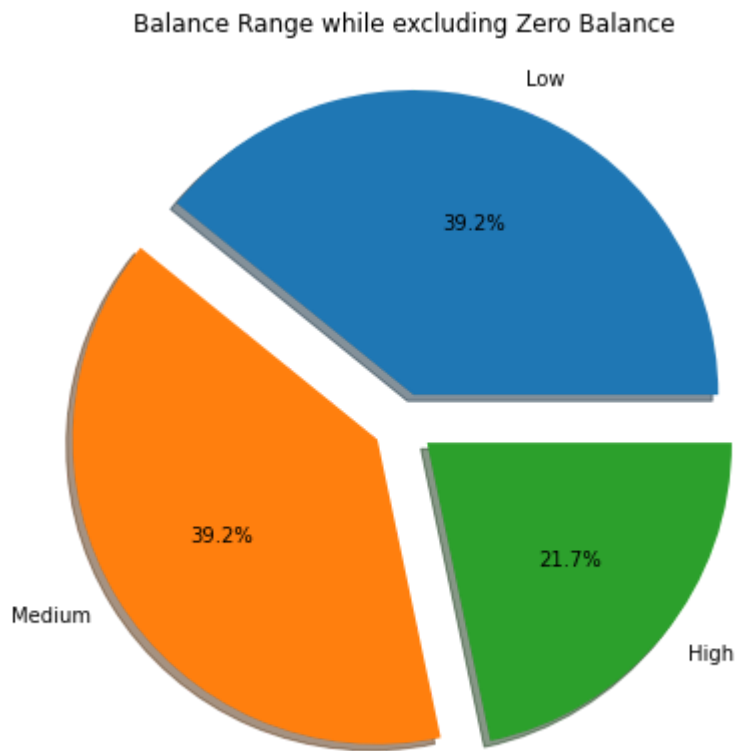
Assumptions

Estimated Salary Range

There seems to be an even distribution of customers with regards to the range of their salary.

Balance Range

50% of the customers have a low bank balance. A lot of these customers have a bank balance of zero. Are they new customers? Some of them have already exited.
If we exclude all zero balance accounts, there is an even distribution of about 40% each between Low and Medium Balance accounts, while 20% of the accounts have a High Balance.

Building the Neural Network Architecture

```
In [30]:   df.drop(["EstimatedSalary_Range", "Balance_Range"], axis=1, inplace=True)
```

```
In [31]:   for cols in df_cat:
               le = LabelEncoder()
               df[cols] = le.fit_transform(df[cols])
```

```
In [32]:   X = df.drop("Exited", axis=1)
           y = df["Exited"]
```

Function to create Neural Network

- **nodes - List of values for nodes per layer. Hidden layers created as per the length of 'nodes'.**

- **act - Activating Function**
- **opt - Optimizer**
- **loss_func - Loss Function**
- **eps - No. of Epochs**
- **batch - No. of samples per batch**
- **os - OverSample**

In [33]:
```python
# Function to build the model

def nn_model(X, y, nodes, act, opt, loss_func, eps, batch=None, os="None"):
    X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_sta

    ss = StandardScaler()
    X_train_ss = ss.fit_transform(X_train)
    X_test_ss = ss.transform(X_test)

    if not os=="None":
        x_os, y_os = os.fit_resample(X_train_ss, y_train)
    else:
        x_os, y_os = X_train_ss, y_train

    model = nn_layers(act,nodes)
    model.summary()

    print()

    print("\nBuilding NN Model\n")
    model.compile(optimizer=opt, loss=loss_func)
    trained_model = model.fit(x_os, y_os, epochs=eps, batch_size=batch)

    lines()

    print("Model Summary")
    plt.figure()
    plt.plot(trained_model.history['loss'])
    plt.show()

    lines()

    print("ROC Curve")
    auc_roc(X_test_ss, y_test, model)

    return [X_test_ss, y_test, model]
```

In [34]:
```python
# Function to create the layers

def nn_layers(act, nodes):
    layers = [tf.keras.layers.Dense(3, activation=act, input_shape=(X.shape[1],))]

    for i in range(len(nodes)):
        if type(nodes[i]) == int:
            layers.append(tf.keras.layers.Dense(nodes[i], activation=act))
        else:
            layers.append(tf.keras.layers.Dropout(nodes[i]))

    layers.append(tf.keras.layers.Dense(1, activation="sigmoid"))

    model = tf.keras.Sequential(layers)
```

```
        return model
```

In [35]:
```python
# Function for evaluating the model

def eval_model(X_test_ss, y_test, model, thres):
    y_pred = model.predict(X_test_ss)
    y_pred = np.where(y_pred > thres, 1, 0)
    print(classification_report(y_test, y_pred))
```

In [36]:
```python
# Function to find the appropriate threshold using AUC-ROC

def auc_roc(X_test_ss, y_test, model):
    proba = model.predict_proba(X_test_ss)[:,-1]
    thresholds = np.arange(0.1, 1.0, 0.1)
    tprs, fprs = [], []

    for each in thresholds:
        y_pred = np.where(proba >= each, 1, 0)
        tn, fp, fn, tp = confusion_matrix(y_test, y_pred).ravel()
        tpr = tp/(tp + fn)
        fpr = fp/(fp + tn)
        tprs.append(tpr)
        fprs.append(fpr)

    plt.figure()
    plt.plot(fprs, tprs, "x--")
    plt.show()

    # fpr, tpr, thres = roc_curve(y_test, proba, pos_label=1)
    print("AUC ROC Score : ", roc_auc_score(y_test, proba))
```

In [37]:
```python
def lines():
    print()
    print("_"*150)
    print()
```

NN Models - Medium Complexity v1.0

The first models will be built with a medium amount of complexity.

Base Model

In [38]:
```python
nodes = [5,6,7,6,5]
result_01 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 50, 100)
```

Model: "sequential"

Layer (type)	Output Shape	Param #
dense (Dense)	(None, 3)	33
dense_1 (Dense)	(None, 5)	20

dense_2 (Dense)	(None, 6)	36
dense_3 (Dense)	(None, 7)	49
dense_4 (Dense)	(None, 6)	48
dense_5 (Dense)	(None, 5)	35
dense_6 (Dense)	(None, 1)	6

```
=================================================================
Total params: 227
Trainable params: 227
Non-trainable params: 0
```
_____

Building NN Model

```
Epoch 1/50
70/70 [==============================] - 0s 1ms/step - loss: 0.6621
Epoch 2/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5366
Epoch 3/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4821
Epoch 4/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4722
Epoch 5/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4635
Epoch 6/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4557
Epoch 7/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4487
Epoch 8/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4432
Epoch 9/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4394
Epoch 10/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4365
Epoch 11/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4341
Epoch 12/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4325
Epoch 13/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4308
Epoch 14/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4292
Epoch 15/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4281
Epoch 16/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4269
Epoch 17/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4258
Epoch 18/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4244
Epoch 19/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4234
Epoch 20/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4220
Epoch 21/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4217
Epoch 22/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4208
Epoch 23/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4203
Epoch 24/50
```

```
70/70 [==============================] - 0s 1ms/step - loss: 0.4192
Epoch 25/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4187
Epoch 26/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4183
Epoch 27/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4175
Epoch 28/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4172
Epoch 29/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4168
Epoch 30/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4161
Epoch 31/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4151
Epoch 32/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4150
Epoch 33/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4144
Epoch 34/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4138
Epoch 35/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4136
Epoch 36/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4132
Epoch 37/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4126
Epoch 38/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4125
Epoch 39/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4118
Epoch 40/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4115
Epoch 41/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4111
Epoch 42/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4105
Epoch 43/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4102
Epoch 44/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4099
Epoch 45/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4099
Epoch 46/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4091
Epoch 47/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4085
Epoch 48/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4082
Epoch 49/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4080
Epoch 50/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4074A: 0s - loss: 0.406
```

_____
_____

Model Summary
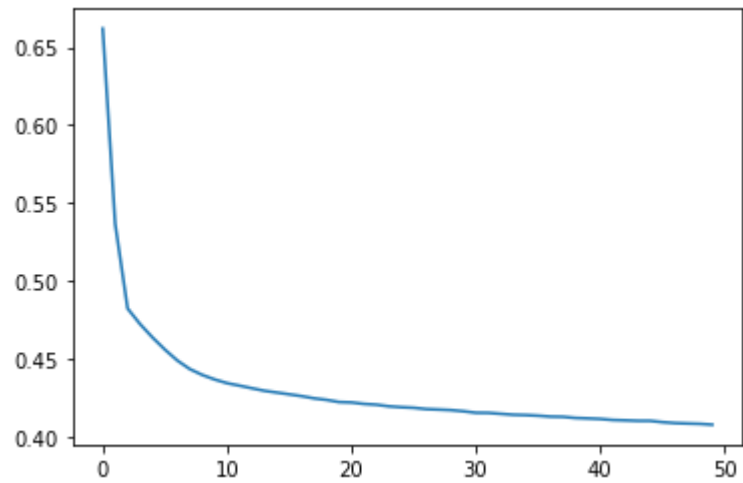
ROC Curve
WARNING:tensorflow:From <ipython-input-36-01991f987c31>:4: Sequential.predict_proba (fro
m tensorflow.python.keras.engine.sequential) is deprecated and will be removed after 202
1-01-01.
Instructions for updating:
Please use `model.predict()` instead.
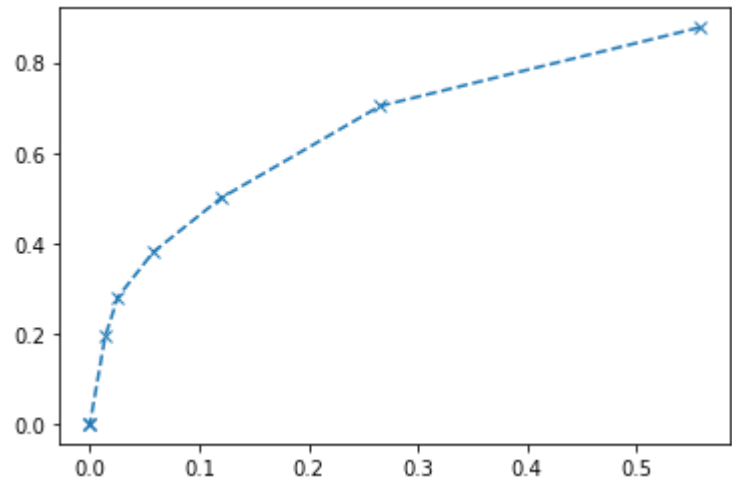
AUC ROC Score : 0.7833884792431601

In [39]:
```python
eval_model(result_01[0], result_01[1], result_01[2], 0.3)
```

	precision	recall	f1-score	support
0	0.87	0.88	0.87	2373
1	0.52	0.50	0.51	627
accuracy			0.80	3000
macro avg	0.70	0.69	0.69	3000
weighted avg	0.80	0.80	0.80	3000

RandomOverSampler

In [40]:
```python
over_sample = RandomOverSampler(sampling_strategy="minority", random_state=1)
```

In [41]:
```python
result_02 = nn_model(X, y, nodes, "relu", "sgd", "binary_crossentropy", 150, 100, over_
```

```
Model: "sequential_1"
_____
Layer (type)                 Output Shape              Param #
=================================================================
dense_7 (Dense)              (None, 3)                 33
_____
dense_8 (Dense)              (None, 5)                 20
_____
dense_9 (Dense)              (None, 6)                 36
_____
dense_10 (Dense)             (None, 7)                 49
_____
dense_11 (Dense)             (None, 6)                 48
_____
dense_12 (Dense)             (None, 5)                 35
_____
dense_13 (Dense)             (None, 1)                 6
=================================================================
Total params: 227
Trainable params: 227
Non-trainable params: 0
_____


Building NN Model

Epoch 1/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6932
Epoch 2/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6932
Epoch 3/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6931
Epoch 4/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6931
Epoch 5/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6931
Epoch 6/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6931
Epoch 7/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6931
Epoch 8/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6931
Epoch 9/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6931
Epoch 10/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6931
Epoch 11/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6931
Epoch 12/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6931
Epoch 13/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6931
Epoch 14/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6931
Epoch 15/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6931
Epoch 16/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6931
Epoch 17/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6931
Epoch 18/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6931
Epoch 19/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6931
Epoch 20/150
```

```
112/112 [==============================] - 0s 1ms/step - loss: 0.6931
Epoch 21/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6931
Epoch 22/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6931
Epoch 23/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6930
Epoch 24/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6930
Epoch 25/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6930
Epoch 26/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6930
Epoch 27/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6930
Epoch 28/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6930
Epoch 29/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6930
Epoch 30/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6930
Epoch 31/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6930
Epoch 32/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6929
Epoch 33/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6929
Epoch 34/150
112/112 [==============================] - ETA: 0s - loss: 0.692 - 0s 2ms/step - loss:
0.6929
Epoch 35/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6929
Epoch 36/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6929
Epoch 37/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6928
Epoch 38/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6928
Epoch 39/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6928
Epoch 40/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6928
Epoch 41/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6928
Epoch 42/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6927
Epoch 43/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6927A: 0s - loss: 0.692
Epoch 44/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6927
Epoch 45/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6926
Epoch 46/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6926
Epoch 47/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6926
Epoch 48/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6925
Epoch 49/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6925
Epoch 50/150
112/112 [==============================] - ETA: 0s - loss: 0.692 - 0s 1ms/step - loss:
0.6925
Epoch 51/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6924
```

```
Epoch 52/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6924
Epoch 53/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6923
Epoch 54/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6923
Epoch 55/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6923
Epoch 56/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6922
Epoch 57/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6922
Epoch 58/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6921
Epoch 59/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6920
Epoch 60/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6920
Epoch 61/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6919
Epoch 62/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6918
Epoch 63/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6917
Epoch 64/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6916
Epoch 65/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6914
Epoch 66/150
112/112 [==============================] - ETA: 0s - loss: 0.691 - 0s 2ms/step - loss:
0.6913
Epoch 67/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6911
Epoch 68/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6908
Epoch 69/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6906
Epoch 70/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6903
Epoch 71/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6899
Epoch 72/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6895A: 0s - loss: 0.69
Epoch 73/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6892
Epoch 74/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6888
Epoch 75/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6883
Epoch 76/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6878
Epoch 77/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6872
Epoch 78/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6865
Epoch 79/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6858
Epoch 80/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6848
Epoch 81/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6837
Epoch 82/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6826
Epoch 83/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6812
```

```
Epoch 84/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6798
Epoch 85/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6782
Epoch 86/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6764
Epoch 87/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6745
Epoch 88/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6722
Epoch 89/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6697
Epoch 90/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6669
Epoch 91/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6638
Epoch 92/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6602
Epoch 93/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6564
Epoch 94/150
112/112 [==============================] - ETA: 0s - loss: 0.652 - 0s 2ms/step - loss:
0.6523
Epoch 95/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6477
Epoch 96/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6431
Epoch 97/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6381
Epoch 98/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6327
Epoch 99/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6276
Epoch 100/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6222
Epoch 101/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6168
Epoch 102/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6114
Epoch 103/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6062
Epoch 104/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6010
Epoch 105/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5956
Epoch 106/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5905
Epoch 107/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5856
Epoch 108/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5810
Epoch 109/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5765
Epoch 110/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5718
Epoch 111/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5677
Epoch 112/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5634
Epoch 113/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5590
Epoch 114/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5546
Epoch 115/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5508
```

```
Epoch 116/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5469
Epoch 117/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5433
Epoch 118/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5394
Epoch 119/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5359
Epoch 120/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5324
Epoch 121/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5287
Epoch 122/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5259
Epoch 123/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5227
Epoch 124/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5203
Epoch 125/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5178
Epoch 126/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5158
Epoch 127/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5139
Epoch 128/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5124
Epoch 129/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5107
Epoch 130/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5098
Epoch 131/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5090
Epoch 132/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5081
Epoch 133/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5071
Epoch 134/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5064
Epoch 135/150
112/112 [==============================] - ETA: 0s - loss: 0.507 - 0s 2ms/step - loss:
0.5065
Epoch 136/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5059
Epoch 137/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5055
Epoch 138/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5051
Epoch 139/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5047
Epoch 140/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5042
Epoch 141/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5039
Epoch 142/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5041
Epoch 143/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5032
Epoch 144/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5035
Epoch 145/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5031
Epoch 146/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5029
Epoch 147/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5026
```

```
Epoch 148/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5023
Epoch 149/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5024
Epoch 150/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5023
```

Model Summary
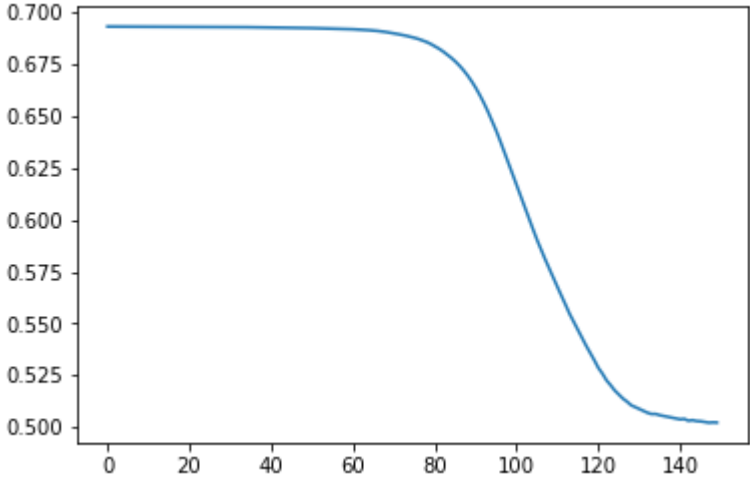
ROC Curve
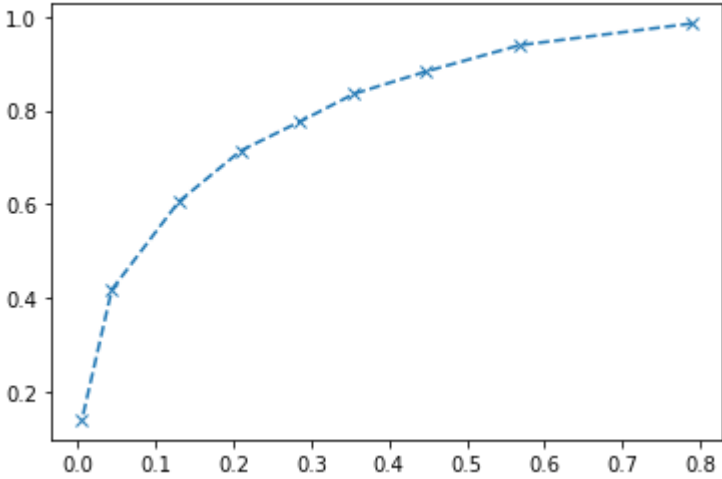
AUC ROC Score :   0.8357381117045766

In [42]: `eval_model(result_02[0], result_02[1], result_02[2], 0.5)`

	precision	recall	f1-score	support
0	0.92	0.71	0.81	2373
1	0.42	0.78	0.54	627
accuracy			0.73	3000
macro avg	0.67	0.75	0.67	3000
weighted avg	0.82	0.73	0.75	3000

SMOTE

In [43]: `over_sample = SMOTE(sampling_strategy="minority", random_state=1)`

In [44]: `result_03 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 150, 100, over`

Model: "sequential_2"

Layer (type)	Output Shape	Param #
dense_14 (Dense)	(None, 3)	33
dense_15 (Dense)	(None, 5)	20
dense_16 (Dense)	(None, 6)	36
dense_17 (Dense)	(None, 7)	49
dense_18 (Dense)	(None, 6)	48
dense_19 (Dense)	(None, 5)	35
dense_20 (Dense)	(None, 1)	6

Total params: 227
Trainable params: 227
Non-trainable params: 0

Building NN Model

```
Epoch 1/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6877
Epoch 2/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6583
Epoch 3/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6238
Epoch 4/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5992
Epoch 5/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5825
Epoch 6/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5713
Epoch 7/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5616
Epoch 8/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5519
Epoch 9/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5446
Epoch 10/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5391
Epoch 11/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5345
Epoch 12/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5303
Epoch 13/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5265
Epoch 14/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5229
Epoch 15/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5192
Epoch 16/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5160
```

```
Epoch 17/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5122
Epoch 18/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5081
Epoch 19/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5041
Epoch 20/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5003
Epoch 21/150
112/112 [==============================] - 0s 3ms/step - loss: 0.4975
Epoch 22/150
112/112 [==============================] - 0s 3ms/step - loss: 0.4946
Epoch 23/150
112/112 [==============================] - 0s 3ms/step - loss: 0.4908
Epoch 24/150
112/112 [==============================] - 0s 3ms/step - loss: 0.4878
Epoch 25/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4854A: 0s - loss: 0
Epoch 26/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4840
Epoch 27/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4822
Epoch 28/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4805
Epoch 29/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4797
Epoch 30/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4782
Epoch 31/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4776
Epoch 32/150
112/112 [==============================] - 0s 3ms/step - loss: 0.4764
Epoch 33/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4755
Epoch 34/150
112/112 [==============================] - 0s 3ms/step - loss: 0.4749
Epoch 35/150
112/112 [==============================] - 0s 3ms/step - loss: 0.4743
Epoch 36/150
112/112 [==============================] - 0s 4ms/step - loss: 0.4743
Epoch 37/150
112/112 [==============================] - 0s 3ms/step - loss: 0.4737
Epoch 38/150
112/112 [==============================] - 0s 3ms/step - loss: 0.4733
Epoch 39/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4729
Epoch 40/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4727
Epoch 41/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4720
Epoch 42/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4717
Epoch 43/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4716
Epoch 44/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4714
Epoch 45/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4717
Epoch 46/150
112/112 [==============================] - 0s 3ms/step - loss: 0.4723
Epoch 47/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4719
Epoch 48/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4708
Epoch 49/150
```

```
112/112 [==============================] - 0s 2ms/step - loss: 0.4710
Epoch 50/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4716
Epoch 51/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4705
Epoch 52/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4710
Epoch 53/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4708
Epoch 54/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4706
Epoch 55/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4712
Epoch 56/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4706
Epoch 57/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4705
Epoch 58/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4703
Epoch 59/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4699
Epoch 60/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4706
Epoch 61/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4709
Epoch 62/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4709
Epoch 63/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4701
Epoch 64/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4703
Epoch 65/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4703
Epoch 66/150
112/112 [==============================] - 0s 4ms/step - loss: 0.4711
Epoch 67/150
112/112 [==============================] - 0s 3ms/step - loss: 0.4711
Epoch 68/150
112/112 [==============================] - 0s 3ms/step - loss: 0.4704
Epoch 69/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4708
Epoch 70/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4702
Epoch 71/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4705
Epoch 72/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4705
Epoch 73/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4704
Epoch 74/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4701
Epoch 75/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4709
Epoch 76/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4708
Epoch 77/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4702
Epoch 78/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4701
Epoch 79/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4702
Epoch 80/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4712
Epoch 81/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4701
```

```
Epoch 82/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4701
Epoch 83/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4698
Epoch 84/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4695
Epoch 85/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4699
Epoch 86/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4697
Epoch 87/150
112/112 [==============================] - 0s 3ms/step - loss: 0.4702
Epoch 88/150
112/112 [==============================] - 0s 3ms/step - loss: 0.4691
Epoch 89/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4699
Epoch 90/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4694
Epoch 91/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4707
Epoch 92/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4703
Epoch 93/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4699
Epoch 94/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4699
Epoch 95/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4697
Epoch 96/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4701
Epoch 97/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4698
Epoch 98/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4691
Epoch 99/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4693
Epoch 100/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4689
Epoch 101/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4691
Epoch 102/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4696
Epoch 103/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4697
Epoch 104/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4695
Epoch 105/150
112/112 [==============================] - 0s 2ms/step - loss: 0.4696
Epoch 106/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4687
Epoch 107/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4702
Epoch 108/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4683
Epoch 109/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4685
Epoch 110/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4685
Epoch 111/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4684
Epoch 112/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4690
Epoch 113/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4685
Epoch 114/150
```

```
        112/112 [==============================] - 0s 2ms/step - loss: 0.4686
        Epoch 115/150
        112/112 [==============================] - 0s 2ms/step - loss: 0.4683
        Epoch 116/150
        112/112 [==============================] - ETA: 0s - loss: 0.470 - 0s 1ms/step - loss:
        0.4681
        Epoch 117/150
        112/112 [==============================] - 0s 2ms/step - loss: 0.4686
        Epoch 118/150
        112/112 [==============================] - 0s 3ms/step - loss: 0.4681
        Epoch 119/150
        112/112 [==============================] - 0s 2ms/step - loss: 0.4691
        Epoch 120/150
        112/112 [==============================] - 0s 3ms/step - loss: 0.4691
        Epoch 121/150
        112/112 [==============================] - 0s 2ms/step - loss: 0.4682
        Epoch 122/150
        112/112 [==============================] - 0s 2ms/step - loss: 0.4694
        Epoch 123/150
        112/112 [==============================] - 0s 3ms/step - loss: 0.4682
        Epoch 124/150
        112/112 [==============================] - 0s 3ms/step - loss: 0.4684
        Epoch 125/150
        112/112 [==============================] - 0s 4ms/step - loss: 0.4675
        Epoch 126/150
        112/112 [==============================] - 0s 3ms/step - loss: 0.4692
        Epoch 127/150
        112/112 [==============================] - 0s 2ms/step - loss: 0.4685
        Epoch 128/150
        112/112 [==============================] - 0s 4ms/step - loss: 0.4690
        Epoch 129/150
        112/112 [==============================] - 1s 5ms/step - loss: 0.4687
        Epoch 130/150
        112/112 [==============================] - 0s 2ms/step - loss: 0.4684
        Epoch 131/150
        112/112 [==============================] - 0s 3ms/step - loss: 0.4682
        Epoch 132/150
        112/112 [==============================] - 0s 3ms/step - loss: 0.4677
        Epoch 133/150
        112/112 [==============================] - 0s 3ms/step - loss: 0.4681
        Epoch 134/150
        112/112 [==============================] - 0s 4ms/step - loss: 0.4681
        Epoch 135/150
        112/112 [==============================] - 0s 4ms/step - loss: 0.4686
        Epoch 136/150
        112/112 [==============================] - 1s 6ms/step - loss: 0.4681
        Epoch 137/150
        112/112 [==============================] - 0s 4ms/step - loss: 0.4678
        Epoch 138/150
        112/112 [==============================] - 0s 3ms/step - loss: 0.4683
        Epoch 139/150
        112/112 [==============================] - 0s 2ms/step - loss: 0.4683
        Epoch 140/150
        112/112 [==============================] - 0s 2ms/step - loss: 0.4677
        Epoch 141/150
        112/112 [==============================] - 0s 2ms/step - loss: 0.4691
        Epoch 142/150
        112/112 [==============================] - 0s 1ms/step - loss: 0.4676
        Epoch 143/150
        112/112 [==============================] - 0s 2ms/step - loss: 0.4684
        Epoch 144/150
        112/112 [==============================] - 0s 2ms/step - loss: 0.4683
        Epoch 145/150
        112/112 [==============================] - 0s 1ms/step - loss: 0.4678
        Epoch 146/150
```

```
112/112 [==============================] - 0s 2ms/step - loss: 0.4677
Epoch 147/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4675
Epoch 148/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4681
Epoch 149/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4681
Epoch 150/150
112/112 [==============================] - 0s 1ms/step - loss: 0.4674
```

Model Summary
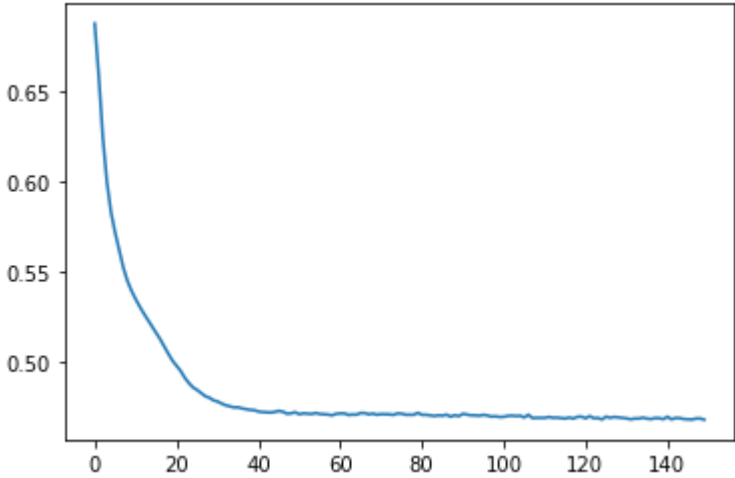
ROC Curve
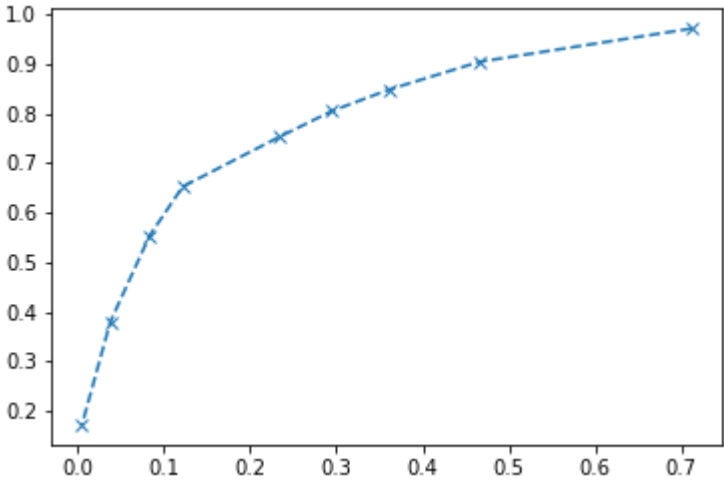
AUC ROC Score :   0.847656147609571

In [45]: `eval_model(result_03[0], result_03[1], result_03[2], 0.5)`

```
              precision    recall  f1-score   support

           0       0.92      0.77      0.84      2373
           1       0.46      0.75      0.57       627

    accuracy                           0.76      3000
   macro avg       0.69      0.76      0.70      3000
weighted avg       0.82      0.76      0.78      3000
```

Assumptions

The Recal score is the highest for the the RandomOverSampler model with medium complexity. However, we would prefer for a better score.

> **0.50 - Base (0.3)**
>
> **0.78 - RandomOverSampler (0.5)**
>
> **0.75 - SMOTE (0.5)**

NN Models - High Complexity v1.0

In this iteration, we will build all three models with a higher complexity. To do this, we will increase the number of hidden layers and also the nodes within the hidden layers.

Base Model

In [46]:
```python
nodes = [5,6,7,8,7,6,5,4]
result_10 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 50, 100)
```

Model: "sequential_3"

Layer (type)	Output Shape	Param #
dense_21 (Dense)	(None, 3)	33
dense_22 (Dense)	(None, 5)	20
dense_23 (Dense)	(None, 6)	36
dense_24 (Dense)	(None, 7)	49
dense_25 (Dense)	(None, 8)	64
dense_26 (Dense)	(None, 7)	63
dense_27 (Dense)	(None, 6)	48
dense_28 (Dense)	(None, 5)	35
dense_29 (Dense)	(None, 4)	24
dense_30 (Dense)	(None, 1)	5

Total params: 377
Trainable params: 377
Non-trainable params: 0

Building NN Model

Epoch 1/50
70/70 [==============================] - 0s 2ms/step - loss: 0.6661
Epoch 2/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5625

```
Epoch 3/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4945
Epoch 4/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4847
Epoch 5/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4755
Epoch 6/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4651
Epoch 7/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4574
Epoch 8/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4507
Epoch 9/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4439
Epoch 10/50
70/70 [==============================] - 0s 3ms/step - loss: 0.4352
Epoch 11/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4261
Epoch 12/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4178
Epoch 13/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4119
Epoch 14/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4080
Epoch 15/50
70/70 [==============================] - 0s 2ms/step - loss: 0.4036
Epoch 16/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3996
Epoch 17/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3980
Epoch 18/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3943
Epoch 19/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3908
Epoch 20/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3882
Epoch 21/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3855
Epoch 22/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3847
Epoch 23/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3826
Epoch 24/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3813
Epoch 25/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3803
Epoch 26/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3794
Epoch 27/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3798
Epoch 28/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3789
Epoch 29/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3789
Epoch 30/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3783
Epoch 31/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3776
Epoch 32/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3765
Epoch 33/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3774
Epoch 34/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3765
Epoch 35/50
```

```
70/70 [==============================] - 0s 2ms/step - loss: 0.3754
Epoch 36/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3747
Epoch 37/50
70/70 [==============================] - 0s 1ms/step - loss: 0.3736
Epoch 38/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3736
Epoch 39/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3747
Epoch 40/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3723
Epoch 41/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3727
Epoch 42/50
70/70 [==============================] - 0s 3ms/step - loss: 0.3700
Epoch 43/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3708
Epoch 44/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3709
Epoch 45/50
70/70 [==============================] - 0s 3ms/step - loss: 0.3696
Epoch 46/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3699
Epoch 47/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3696
Epoch 48/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3690
Epoch 49/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3679
Epoch 50/50
70/70 [==============================] - 0s 2ms/step - loss: 0.3678
```

_____
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Model Summary

_____
_____
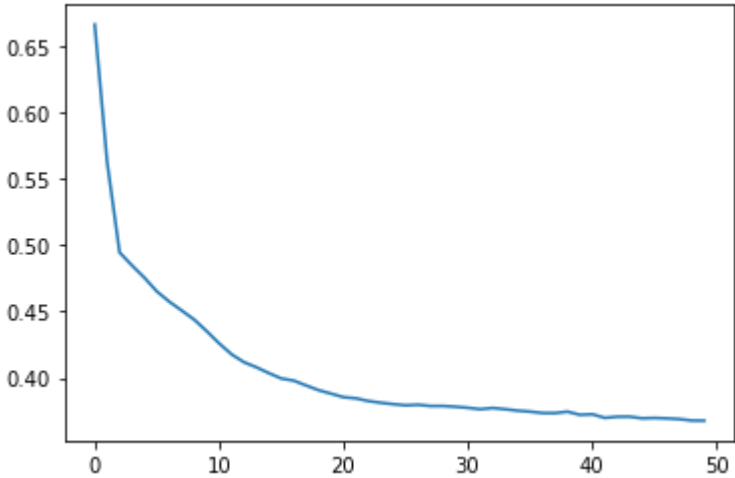
ROC Curve
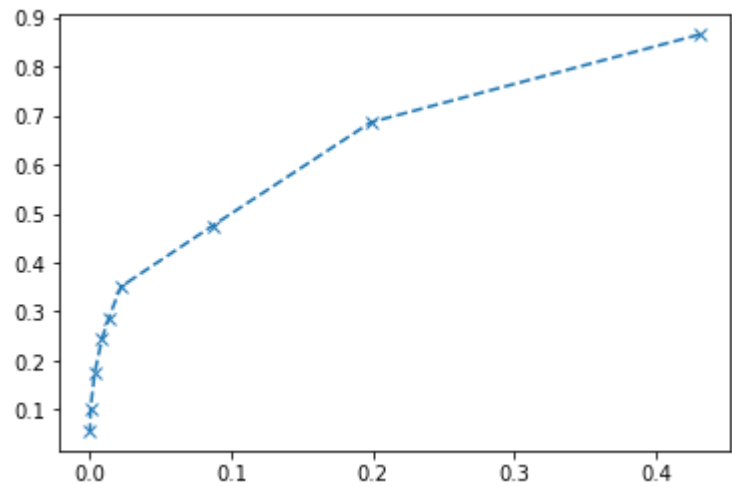
AUC ROC Score :   0.8311022931423491

```
In [47]:  eval_model(result_10[0], result_10[1], result_10[2], 0.3)
```

	precision	recall	f1-score	support
0	0.87	0.91	0.89	2373
1	0.59	0.48	0.53	627
accuracy			0.82	3000
macro avg	0.73	0.69	0.71	3000
weighted avg	0.81	0.82	0.81	3000

```
In [48]:  eval_model(result_10[0], result_10[1], result_10[2], 0.2)
```

	precision	recall	f1-score	support
0	0.91	0.80	0.85	2373
1	0.48	0.69	0.56	627
accuracy			0.78	3000
macro avg	0.69	0.74	0.71	3000
weighted avg	0.82	0.78	0.79	3000

RandomOverSampler

```
In [49]:  over_sample = RandomOverSampler(sampling_strategy="minority", random_state=1)
          result_11 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 50, 100, over_
```

Model: "sequential_4"

Layer (type)	Output Shape	Param #
dense_31 (Dense)	(None, 3)	33
dense_32 (Dense)	(None, 5)	20
dense_33 (Dense)	(None, 6)	36
dense_34 (Dense)	(None, 7)	49
dense_35 (Dense)	(None, 8)	64

```
dense_36 (Dense)              (None, 7)              63
_____
dense_37 (Dense)              (None, 6)              48
_____
dense_38 (Dense)              (None, 5)              35
_____
dense_39 (Dense)              (None, 4)              24
_____
dense_40 (Dense)              (None, 1)              5
=================================================================
Total params: 377
Trainable params: 377
Non-trainable params: 0
_____


Building NN Model

Epoch 1/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6755
Epoch 2/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6442
Epoch 3/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6119
Epoch 4/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5949
Epoch 5/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5860A: 0s - loss: 0.5
Epoch 6/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5802
Epoch 7/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5721
Epoch 8/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5603
Epoch 9/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5438
Epoch 10/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5319
Epoch 11/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5207
Epoch 12/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5177
Epoch 13/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5161
Epoch 14/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5140
Epoch 15/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5135
Epoch 16/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5119
Epoch 17/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5126
Epoch 18/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5116
Epoch 19/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5105
Epoch 20/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5100
Epoch 21/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5093
Epoch 22/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5082
Epoch 23/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5066
Epoch 24/50
```

```
112/112 [==============================] - 0s 2ms/step - loss: 0.5069
Epoch 25/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5058
Epoch 26/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5052
Epoch 27/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5049
Epoch 28/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5056
Epoch 29/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5029
Epoch 30/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5026
Epoch 31/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5020
Epoch 32/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5027
Epoch 33/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5018
Epoch 34/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5012
Epoch 35/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5011
Epoch 36/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5006
Epoch 37/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4999
Epoch 38/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4995
Epoch 39/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4986
Epoch 40/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4983
Epoch 41/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4984
Epoch 42/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4967
Epoch 43/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4961
Epoch 44/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4960
Epoch 45/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4954
Epoch 46/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4952
Epoch 47/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4947
Epoch 48/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4951
Epoch 49/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4953
Epoch 50/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4938
```

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_____

Model Summary
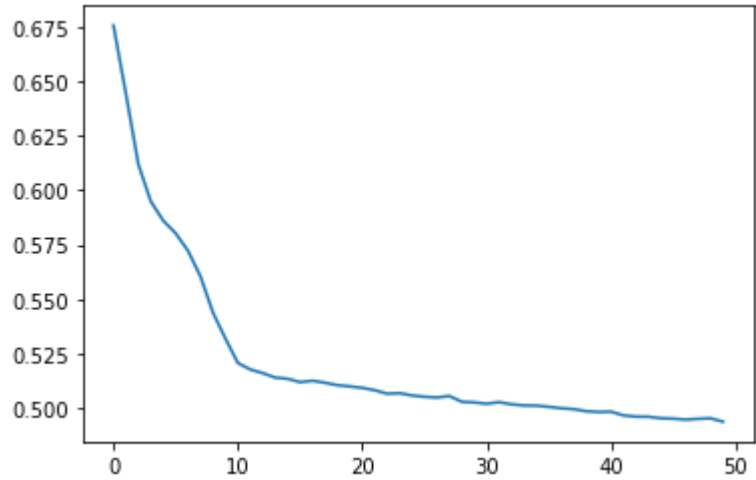
ROC Curve
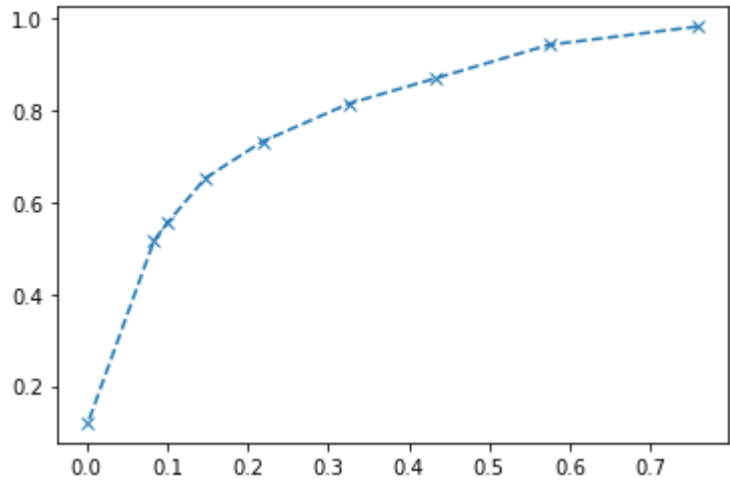
AUC ROC Score : 0.8356127648163045

```
In [50]:  eval_model(result_11[0], result_11[1], result_11[2], 0.5)
```

```
              precision    recall  f1-score   support

           0       0.92      0.78      0.84      2373
           1       0.47      0.73      0.57       627

    accuracy                           0.77      3000
   macro avg       0.69      0.76      0.71      3000
weighted avg       0.82      0.77      0.79      3000
```

SMOTE

```
In [51]:  over_sample = SMOTE(sampling_strategy="minority", random_state=1)
          result_12 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 50, 100, over_
```

Model: "sequential_5"

```
_____
Layer (type)                 Output Shape              Param #
===============================================================
dense_41 (Dense)             (None, 3)                 33
_____
```

dense_42 (Dense)	(None, 5)	20
dense_43 (Dense)	(None, 6)	36
dense_44 (Dense)	(None, 7)	49
dense_45 (Dense)	(None, 8)	64
dense_46 (Dense)	(None, 7)	63
dense_47 (Dense)	(None, 6)	48
dense_48 (Dense)	(None, 5)	35
dense_49 (Dense)	(None, 4)	24
dense_50 (Dense)	(None, 1)	5

```
=================================================================
Total params: 377
Trainable params: 377
Non-trainable params: 0
_____


Building NN Model

Epoch 1/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6883
Epoch 2/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6503
Epoch 3/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6091
Epoch 4/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5850
Epoch 5/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5693
Epoch 6/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5600
Epoch 7/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5496
Epoch 8/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5409
Epoch 9/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5333
Epoch 10/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5281
Epoch 11/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5229
Epoch 12/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5194
Epoch 13/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5154
Epoch 14/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5125
Epoch 15/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5089
Epoch 16/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5064
Epoch 17/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5048
Epoch 18/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5013
Epoch 19/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5007
Epoch 20/50
```

```
112/112 [==============================] - 0s 2ms/step - loss: 0.4980
Epoch 21/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4965
Epoch 22/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4955
Epoch 23/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4937
Epoch 24/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4923
Epoch 25/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4924
Epoch 26/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4911
Epoch 27/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4905
Epoch 28/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4897
Epoch 29/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4886
Epoch 30/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4877
Epoch 31/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4866
Epoch 32/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4871
Epoch 33/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4866
Epoch 34/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4864
Epoch 35/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4843
Epoch 36/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4846
Epoch 37/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4849A: 0s - loss: 0.49
Epoch 38/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4842
Epoch 39/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4836
Epoch 40/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4840
Epoch 41/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4827
Epoch 42/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4832
Epoch 43/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4827
Epoch 44/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4826
Epoch 45/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4826
Epoch 46/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4816
Epoch 47/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4816
Epoch 48/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4816
Epoch 49/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4807
Epoch 50/50
112/112 [==============================] - 0s 2ms/step - loss: 0.4803
```

_____
_____

Model Summary

_____

_____
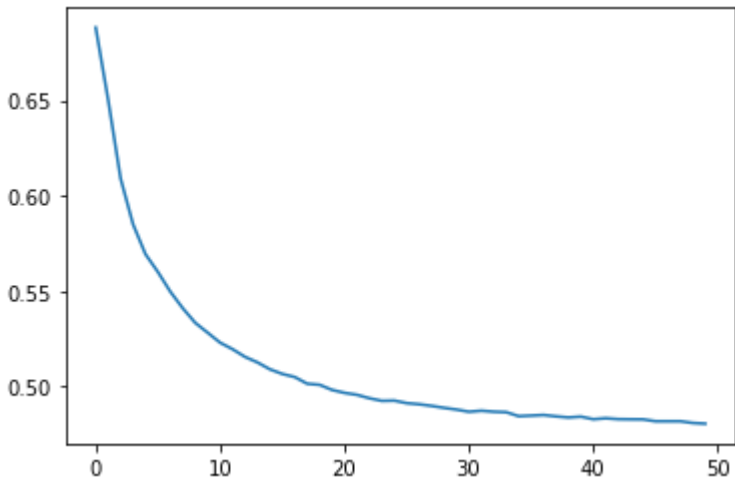
ROC Curve
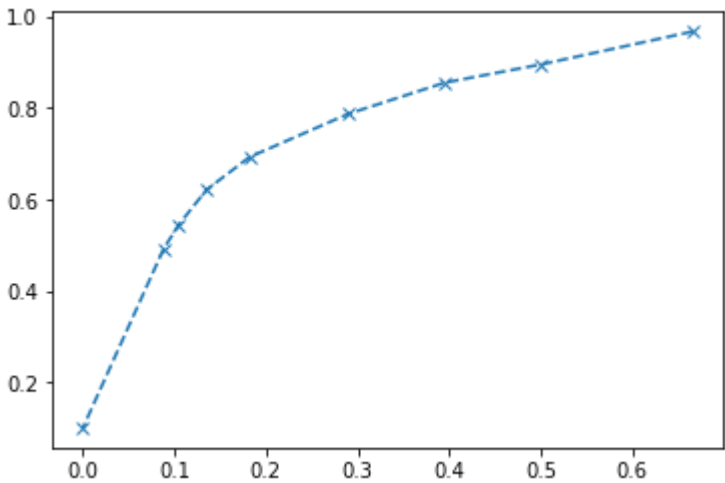
AUC ROC Score : 0.826390527135753

In [52]:   `eval_model(result_12[0], result_12[1], result_12[2], 0.5)`

	precision	recall	f1-score	support
0	0.91	0.82	0.86	2373
1	0.50	0.69	0.58	627
accuracy			0.79	3000
macro avg	0.71	0.76	0.72	3000
weighted avg	0.82	0.79	0.80	3000

Assumptions

As we've increased the complexity, there has been some change with Recall scores. RandomOverSampler got the higher score. And we have taken two threshold values for the Base model.

0.48, 0.69 - Base (0.3, 0.2)

0.73 - RandomOverSampler (0.5)

0.69 - SMOTE (0.5)

NN Models - Low Complexity v1.0

We will now create the models with very low complexity. There will be only one hidden layer in this architecture.

Base Model

In [53]:
```python
nodes = [3]
result_20 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 50)
```

```
Model: "sequential_6"
_____
Layer (type)                 Output Shape              Param #
=================================================================
dense_51 (Dense)             (None, 3)                 33
_____
dense_52 (Dense)             (None, 3)                 12
_____
dense_53 (Dense)             (None, 1)                 4
=================================================================
Total params: 49
Trainable params: 49
Non-trainable params: 0
_____


Building NN Model

Epoch 1/50
219/219 [==============================] - 0s 1ms/step - loss: 0.6153
Epoch 2/50
219/219 [==============================] - 0s 2ms/step - loss: 0.4977
Epoch 3/50
219/219 [==============================] - 0s 2ms/step - loss: 0.4699
Epoch 4/50
219/219 [==============================] - 0s 2ms/step - loss: 0.4590A: 0s - loss:
Epoch 5/50
219/219 [==============================] - 0s 2ms/step - loss: 0.4515
Epoch 6/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4463
Epoch 7/50
219/219 [==============================] - 0s 2ms/step - loss: 0.4428
Epoch 8/50
219/219 [==============================] - 0s 2ms/step - loss: 0.4405
Epoch 9/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4388
Epoch 10/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4376
Epoch 11/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4360
Epoch 12/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4345
Epoch 13/50
```

```
219/219 [==============================] - 0s 1ms/step - loss: 0.4327
Epoch 14/50
219/219 [==============================] - 0s 2ms/step - loss: 0.4310
Epoch 15/50
219/219 [==============================] - 0s 2ms/step - loss: 0.4288
Epoch 16/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4263
Epoch 17/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4237
Epoch 18/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4218
Epoch 19/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4198
Epoch 20/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4176
Epoch 21/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4154
Epoch 22/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4134
Epoch 23/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4114
Epoch 24/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4093
Epoch 25/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4074
Epoch 26/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4058
Epoch 27/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4037
Epoch 28/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4018
Epoch 29/50
219/219 [==============================] - 0s 2ms/step - loss: 0.3999
Epoch 30/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3981
Epoch 31/50
219/219 [==============================] - 0s 2ms/step - loss: 0.3963
Epoch 32/50
219/219 [==============================] - 0s 2ms/step - loss: 0.3944
Epoch 33/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3923
Epoch 34/50
219/219 [==============================] - 0s 2ms/step - loss: 0.3902
Epoch 35/50
219/219 [==============================] - 1s 2ms/step - loss: 0.3885
Epoch 36/50
219/219 [==============================] - 0s 2ms/step - loss: 0.3860
Epoch 37/50
219/219 [==============================] - 0s 2ms/step - loss: 0.3837
Epoch 38/50
219/219 [==============================] - 1s 3ms/step - loss: 0.3817
Epoch 39/50
219/219 [==============================] - 1s 3ms/step - loss: 0.3798
Epoch 40/50
219/219 [==============================] - 1s 3ms/step - loss: 0.3780
Epoch 41/50
219/219 [==============================] - 0s 2ms/step - loss: 0.3763
Epoch 42/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3750
Epoch 43/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3733
Epoch 44/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3719
Epoch 45/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3706
```

```
Epoch 46/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3697
Epoch 47/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3682
Epoch 48/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3670
Epoch 49/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3665
Epoch 50/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3655
```

Model Summary
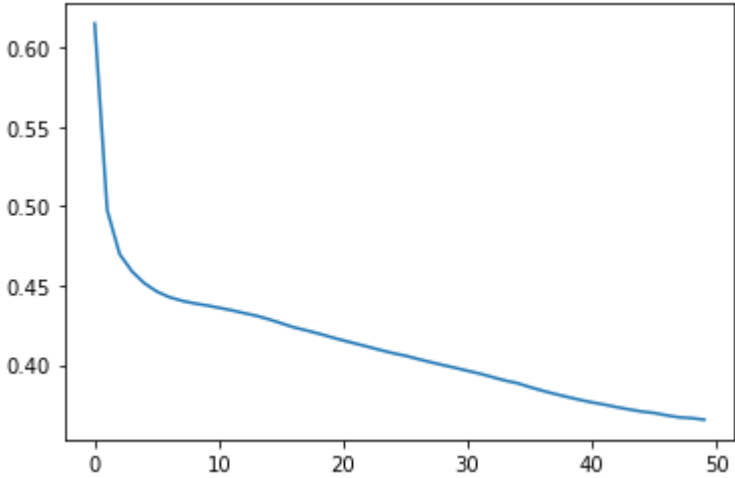
ROC Curve
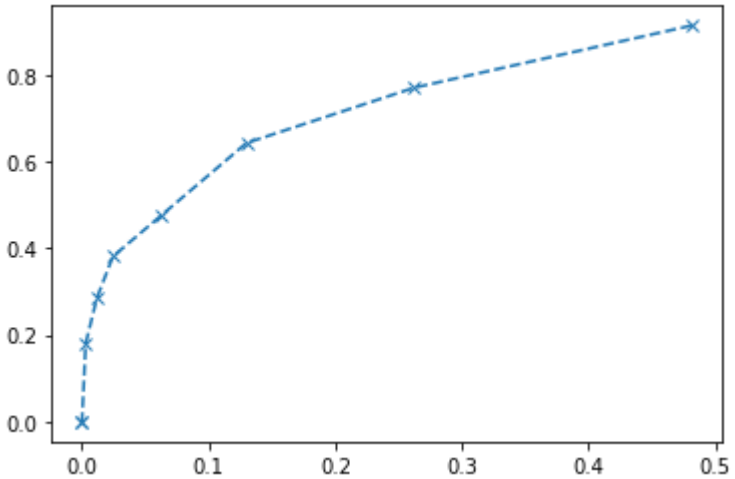
AUC ROC Score :   0.8453743637721282

In [54]: `eval_model(result_20[0], result_20[1], result_20[2], 0.3)`

	precision	recall	f1-score	support
0	0.90	0.87	0.89	2373
1	0.57	0.64	0.60	627
accuracy			0.82	3000
macro avg	0.73	0.76	0.74	3000

```
weighted avg       0.83      0.82      0.83      3000
```

RandomOverSampler

In [55]:
```python
over_sample = RandomOverSampler(sampling_strategy='minority', random_state=1)
result_21 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 150, os=over_s
```

Model: "sequential_7"

```
_____
Layer (type)                 Output Shape              Param #
=================================================================
dense_54 (Dense)             (None, 3)                 33
_____
dense_55 (Dense)             (None, 3)                 12
_____
dense_56 (Dense)             (None, 1)                 4
=================================================================
Total params: 49
Trainable params: 49
Non-trainable params: 0
_____


Building NN Model

Epoch 1/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6989
Epoch 2/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6854
Epoch 3/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6578
Epoch 4/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6203
Epoch 5/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5992
Epoch 6/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5774
Epoch 7/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5593
Epoch 8/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5452
Epoch 9/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5342
Epoch 10/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5263
Epoch 11/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5203
Epoch 12/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5156
Epoch 13/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5117
Epoch 14/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5089
Epoch 15/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5068
Epoch 16/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5052
Epoch 17/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5034
Epoch 18/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5023
```

```
Epoch 19/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5016
Epoch 20/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5008
Epoch 21/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4999
Epoch 22/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4997
Epoch 23/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4990
Epoch 24/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4985
Epoch 25/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4984
Epoch 26/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4978
Epoch 27/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4975
Epoch 28/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4966
Epoch 29/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4954
Epoch 30/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4944
Epoch 31/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4933
Epoch 32/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4922
Epoch 33/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4910
Epoch 34/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4897
Epoch 35/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4890
Epoch 36/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4876
Epoch 37/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4872
Epoch 38/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4865
Epoch 39/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4858
Epoch 40/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4852
Epoch 41/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4845
Epoch 42/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4841
Epoch 43/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4836
Epoch 44/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4832
Epoch 45/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4827
Epoch 46/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4825
Epoch 47/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4821
Epoch 48/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4815
Epoch 49/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4819
Epoch 50/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4816
Epoch 51/150
```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.4814
Epoch 52/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4812
Epoch 53/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4809
Epoch 54/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4809
Epoch 55/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4809
Epoch 56/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4806
Epoch 57/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4805
Epoch 58/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4805
Epoch 59/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4804
Epoch 60/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4804
Epoch 61/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4803
Epoch 62/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4800
Epoch 63/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4801
Epoch 64/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4798
Epoch 65/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4798
Epoch 66/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4799
Epoch 67/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4799
Epoch 68/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4799
Epoch 69/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4797
Epoch 70/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4796
Epoch 71/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4798
Epoch 72/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4798
Epoch 73/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4798
Epoch 74/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4795
Epoch 75/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4796
Epoch 76/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4795
Epoch 77/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4795
Epoch 78/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4795
Epoch 79/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4794
Epoch 80/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4794
Epoch 81/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4791
Epoch 82/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4795
Epoch 83/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4791
```

```
Epoch 84/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4793
Epoch 85/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4790
Epoch 86/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4792
Epoch 87/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4791
Epoch 88/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4791
Epoch 89/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4789
Epoch 90/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4791
Epoch 91/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4790
Epoch 92/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4790
Epoch 93/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4790
Epoch 94/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4787
Epoch 95/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4790
Epoch 96/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4788
Epoch 97/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4791
Epoch 98/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4788
Epoch 99/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4786
Epoch 100/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4787
Epoch 101/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4789
Epoch 102/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4787
Epoch 103/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4788
Epoch 104/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4788
Epoch 105/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4788
Epoch 106/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4788
Epoch 107/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4787
Epoch 108/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4787
Epoch 109/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4787
Epoch 110/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4785
Epoch 111/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4787
Epoch 112/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4787
Epoch 113/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4786
Epoch 114/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4784
Epoch 115/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4787
Epoch 116/150
```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.4785
Epoch 117/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4783
Epoch 118/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4786
Epoch 119/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4782
Epoch 120/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4784
Epoch 121/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4781
Epoch 122/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4783
Epoch 123/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4782
Epoch 124/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4783
Epoch 125/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4781
Epoch 126/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4780
Epoch 127/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4783
Epoch 128/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4784
Epoch 129/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4777
Epoch 130/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4781
Epoch 131/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4780
Epoch 132/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4781
Epoch 133/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4781
Epoch 134/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4783
Epoch 135/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4781
Epoch 136/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4781
Epoch 137/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4780
Epoch 138/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4780
Epoch 139/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4780
Epoch 140/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4779
Epoch 141/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4778
Epoch 142/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4779
Epoch 143/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4780
Epoch 144/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4779
Epoch 145/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4780
Epoch 146/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4778
Epoch 147/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4779
Epoch 148/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4780
```

```
Epoch 149/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4780
Epoch 150/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4779
```

Model Summary
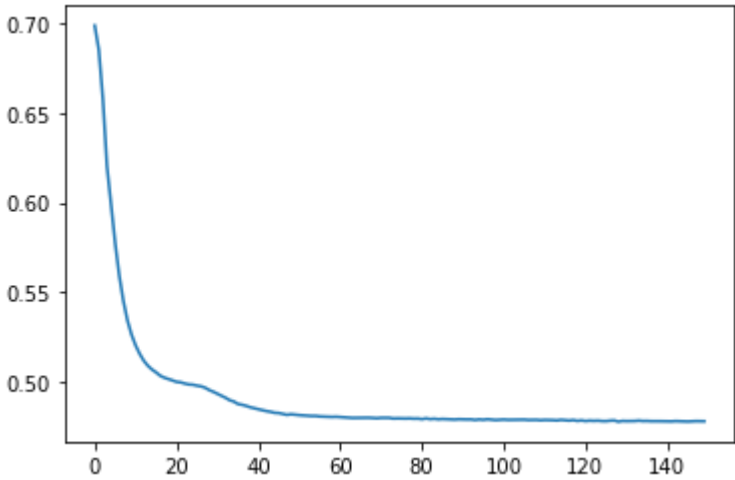
ROC Curve
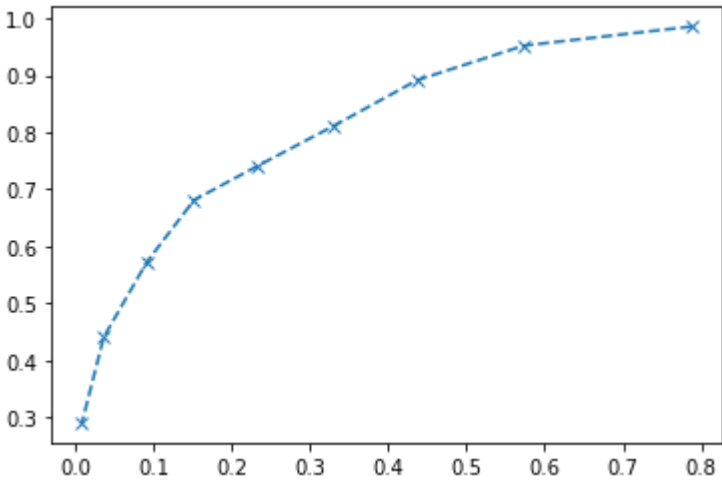
AUC ROC Score : 0.8486451446395554

In [56]: `eval_model(result_21[0], result_21[1], result_21[2], 0.5)`

	precision	recall	f1-score	support
0	0.92	0.77	0.84	2373
1	0.46	0.74	0.57	627
accuracy			0.76	3000
macro avg	0.69	0.75	0.70	3000
weighted avg	0.82	0.76	0.78	3000

SMOTE

In [57]:
```python
over_sample = SMOTE(sampling_strategy='minority', random_state=1)
result_22 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 150, os=over_s
```

Model: "sequential_8"

Layer (type)	Output Shape	Param #
dense_57 (Dense)	(None, 3)	33
dense_58 (Dense)	(None, 3)	12
dense_59 (Dense)	(None, 1)	4

Total params: 49
Trainable params: 49
Non-trainable params: 0

Building NN Model

Epoch 1/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6818
Epoch 2/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6494
Epoch 3/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5873
Epoch 4/150
350/350 [==============================] - 0s 977us/step - loss: 0.5648
Epoch 5/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5585
Epoch 6/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5552
Epoch 7/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5525
Epoch 8/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5508
Epoch 9/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5494
Epoch 10/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5482
Epoch 11/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5476
Epoch 12/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5467
Epoch 13/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5462
Epoch 14/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5458
Epoch 15/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5453A: 0s - loss: 0
Epoch 16/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5448
Epoch 17/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5445
Epoch 18/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5440
Epoch 19/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5436
Epoch 20/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5435
Epoch 21/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5430
Epoch 22/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5429

```
Epoch 23/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5426
Epoch 24/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5425
Epoch 25/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5421
Epoch 26/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5418
Epoch 27/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5418
Epoch 28/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5414
Epoch 29/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5411
Epoch 30/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5405
Epoch 31/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5401
Epoch 32/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5395
Epoch 33/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5392
Epoch 34/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5385
Epoch 35/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5381
Epoch 36/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5378
Epoch 37/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5370
Epoch 38/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5367
Epoch 39/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5364
Epoch 40/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5357
Epoch 41/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5358
Epoch 42/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5353
Epoch 43/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5350
Epoch 44/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5347
Epoch 45/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5344
Epoch 46/150
350/350 [==============================] - 0s 932us/step - loss: 0.5343
Epoch 47/150
350/350 [==============================] - 0s 975us/step - loss: 0.5341
Epoch 48/150
350/350 [==============================] - 0s 952us/step - loss: 0.5339
Epoch 49/150
350/350 [==============================] - 0s 976us/step - loss: 0.5336
Epoch 50/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5334
Epoch 51/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5333
Epoch 52/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5330
Epoch 53/150
350/350 [==============================] - 0s 971us/step - loss: 0.5329
Epoch 54/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5327
Epoch 55/150
```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.5325
Epoch 56/150
350/350 [==============================] - 0s 789us/step - loss: 0.5325
Epoch 57/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5321
Epoch 58/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5319
Epoch 59/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5319
Epoch 60/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5318
Epoch 61/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5318
Epoch 62/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5316
Epoch 63/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5315
Epoch 64/150
350/350 [==============================] - 0s 923us/step - loss: 0.5313
Epoch 65/150
350/350 [==============================] - 0s 912us/step - loss: 0.5315
Epoch 66/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5315
Epoch 67/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5312
Epoch 68/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5309
Epoch 69/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5309
Epoch 70/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5308
Epoch 71/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5310
Epoch 72/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5309
Epoch 73/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5306
Epoch 74/150
350/350 [==============================] - 1s 2ms/step - loss: 0.5306
Epoch 75/150
350/350 [==============================] - 1s 1ms/step - loss: 0.5305
Epoch 76/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5305
Epoch 77/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5308
Epoch 78/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5305
Epoch 79/150
350/350 [==============================] - 0s 934us/step - loss: 0.5305
Epoch 80/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5303
Epoch 81/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5304
Epoch 82/150
350/350 [==============================] - 0s 983us/step - loss: 0.5304
Epoch 83/150
350/350 [==============================] - 0s 898us/step - loss: 0.5299
Epoch 84/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5303
Epoch 85/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5303
Epoch 86/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5301
Epoch 87/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5300
```

```
Epoch 88/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5300
Epoch 89/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5299
Epoch 90/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5300
Epoch 91/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5299
Epoch 92/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5296
Epoch 93/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5298
Epoch 94/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5301
Epoch 95/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5298
Epoch 96/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5296
Epoch 97/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5296
Epoch 98/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5296
Epoch 99/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5296
Epoch 100/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5297
Epoch 101/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5293
Epoch 102/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5294
Epoch 103/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5298
Epoch 104/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5292
Epoch 105/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5296
Epoch 106/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5297
Epoch 107/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5295
Epoch 108/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5295
Epoch 109/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5295
Epoch 110/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5295
Epoch 111/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5294
Epoch 112/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5296
Epoch 113/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5294
Epoch 114/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5292
Epoch 115/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5293
Epoch 116/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5294
Epoch 117/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5291
Epoch 118/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5292
Epoch 119/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5293
Epoch 120/150
```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.5290
Epoch 121/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5291
Epoch 122/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5291
Epoch 123/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5291
Epoch 124/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5291A: 0s - loss: 0.
Epoch 125/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5290
Epoch 126/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5287
Epoch 127/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5288
Epoch 128/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5288
Epoch 129/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5289
Epoch 130/150
350/350 [==============================] - 1s 1ms/step - loss: 0.5287
Epoch 131/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5287
Epoch 132/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5286
Epoch 133/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5286
Epoch 134/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5287
Epoch 135/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5284
Epoch 136/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5284
Epoch 137/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5285
Epoch 138/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5281
Epoch 139/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5286
Epoch 140/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5285
Epoch 141/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5283
Epoch 142/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5282
Epoch 143/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5281
Epoch 144/150
350/350 [==============================] - 0s 989us/step - loss: 0.5282
Epoch 145/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5278
Epoch 146/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5282
Epoch 147/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5281
Epoch 148/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5283
Epoch 149/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5279
Epoch 150/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5275
```

_____
_____

Model Summary

_____

_____
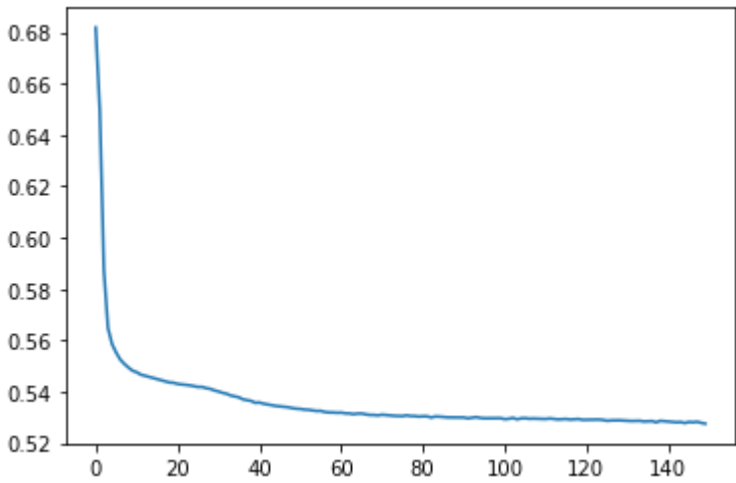
ROC Curve
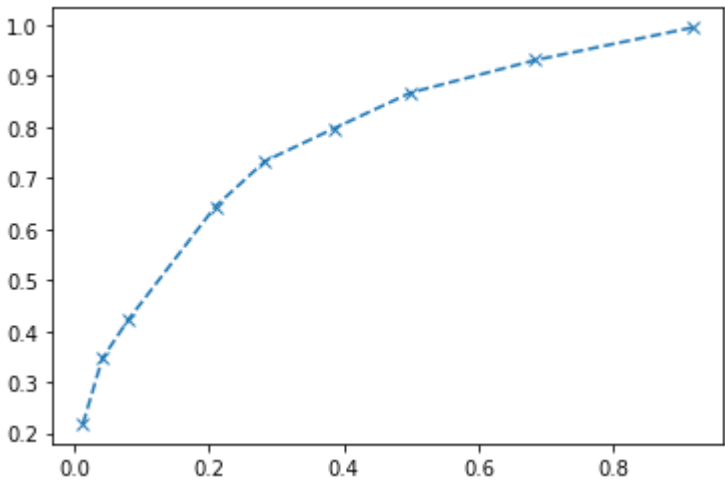
AUC ROC Score :   0.7958294099421253

In [58]:   `eval_model(result_22[0], result_22[1], result_22[2], 0.5)`

```
               precision    recall  f1-score   support

           0       0.91      0.72      0.80      2373
           1       0.41      0.73      0.52       627

    accuracy                           0.72      3000
   macro avg       0.66      0.73      0.66      3000
weighted avg       0.81      0.72      0.74      3000
```

Assumptions

RandomOverSampler showed the same results as from the previous iteration.

0.63 - Base (0.5)

0.74 - RandomOverSampler (0.5)

0.73 - SMOTE (0.5)

NN Models - Low Complexity v1.1

The models in this iteration will have two hidden layers.

Base Model

In [59]:
```
nodes = [3,3]
result_30 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 50)
```

```
Model: "sequential_9"
_____
Layer (type)                 Output Shape              Param #
=================================================================
dense_60 (Dense)             (None, 3)                 33
_____
dense_61 (Dense)             (None, 3)                 12
_____
dense_62 (Dense)             (None, 3)                 12
_____
dense_63 (Dense)             (None, 1)                 4
=================================================================
Total params: 61
Trainable params: 61
Non-trainable params: 0
_____


Building NN Model

Epoch 1/50
219/219 [==============================] - 0s 911us/step - loss: 0.6720
Epoch 2/50
219/219 [==============================] - 0s 1ms/step - loss: 0.5565
Epoch 3/50
219/219 [==============================] - 0s 1ms/step - loss: 0.5139
Epoch 4/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4986
Epoch 5/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4863
Epoch 6/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4685
Epoch 7/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4529
Epoch 8/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4442
Epoch 9/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4405
Epoch 10/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4380
Epoch 11/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4362
Epoch 12/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4342
Epoch 13/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4317
Epoch 14/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4294
Epoch 15/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4265
Epoch 16/50
```

```
219/219 [==============================] - 0s 1ms/step - loss: 0.4235
Epoch 17/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4203
Epoch 18/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4171
Epoch 19/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4140
Epoch 20/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4103
Epoch 21/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4065
Epoch 22/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4025
Epoch 23/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3990
Epoch 24/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3952
Epoch 25/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3913
Epoch 26/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3886
Epoch 27/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3858
Epoch 28/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3831
Epoch 29/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3807
Epoch 30/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3780
Epoch 31/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3759
Epoch 32/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3739
Epoch 33/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3716
Epoch 34/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3693
Epoch 35/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3676
Epoch 36/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3656
Epoch 37/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3644
Epoch 38/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3623
Epoch 39/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3611
Epoch 40/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3600
Epoch 41/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3589
Epoch 42/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3583
Epoch 43/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3572
Epoch 44/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3562
Epoch 45/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3560
Epoch 46/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3553
Epoch 47/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3551
Epoch 48/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3540
```

```
Epoch 49/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3542
Epoch 50/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3533
```

_____

_____

Model Summary

_____

_____
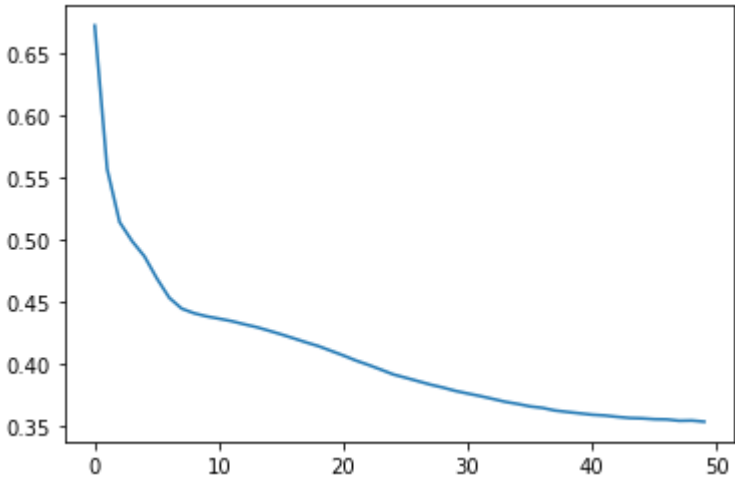
ROC Curve
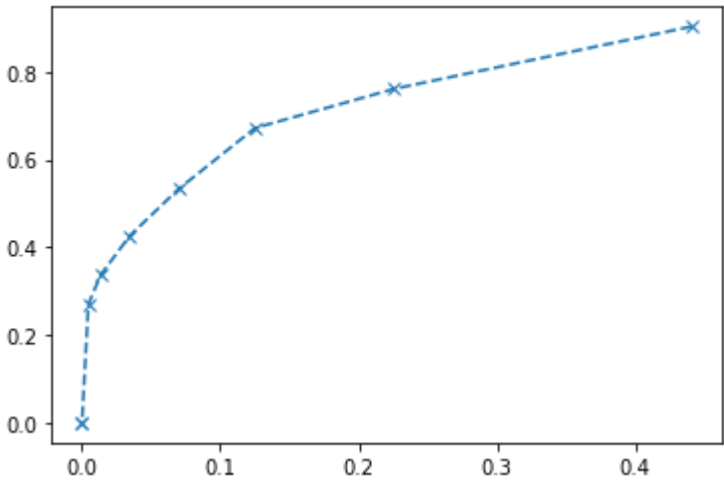
AUC ROC Score :   0.854921562420398

In [60]: `eval_model(result_30[0], result_30[1], result_30[2], 0.3)`

	precision	recall	f1-score	support
0	0.91	0.87	0.89	2373
1	0.59	0.67	0.63	627
accuracy			0.83	3000
macro avg	0.75	0.77	0.76	3000
weighted avg	0.84	0.83	0.84	3000

In [61]: `eval_model(result_30[0], result_30[1], result_30[2], 0.2)`

	precision	recall	f1-score	support

```
              0        0.92      0.77      0.84      2373
              1        0.47      0.76      0.58       627

       accuracy                            0.77      3000
      macro avg        0.70      0.77      0.71      3000
   weighted avg        0.83      0.77      0.79      3000
```

RandomOverSampler

In [62]:
```
over_sample = RandomOverSampler(sampling_strategy='minority', random_state=1)
result_31 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 150, os=over_s
```

Model: "sequential_10"

_____
Layer (type)	Output Shape	Param #
===
dense_64 (Dense)	(None, 3)	33
dense_65 (Dense)	(None, 3)	12
dense_66 (Dense)	(None, 3)	12
dense_67 (Dense)	(None, 1)	4
===

Total params: 61
Trainable params: 61
Non-trainable params: 0

_____

Building NN Model

```
Epoch 1/150
350/350 [==============================] - 0s 884us/step - loss: 0.6947
Epoch 2/150
350/350 [==============================] - 0s 935us/step - loss: 0.6871
Epoch 3/150
350/350 [==============================] - 0s 931us/step - loss: 0.6550
Epoch 4/150
350/350 [==============================] - 0s 972us/step - loss: 0.6225
Epoch 5/150
350/350 [==============================] - 0s 921us/step - loss: 0.6055
Epoch 6/150
350/350 [==============================] - 0s 937us/step - loss: 0.5949
Epoch 7/150
350/350 [==============================] - 0s 951us/step - loss: 0.5868
Epoch 8/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5801
Epoch 9/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5742
Epoch 10/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5684
Epoch 11/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5628
Epoch 12/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5572
Epoch 13/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5513
Epoch 14/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5455
Epoch 15/150
```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.5403
Epoch 16/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5353
Epoch 17/150
350/350 [==============================] - 0s 986us/step - loss: 0.5310
Epoch 18/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5270
Epoch 19/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5231
Epoch 20/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5180
Epoch 21/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5143
Epoch 22/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5112
Epoch 23/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5084
Epoch 24/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5068
Epoch 25/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5048
Epoch 26/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5034
Epoch 27/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5024
Epoch 28/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5007
Epoch 29/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5002
Epoch 30/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4996
Epoch 31/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4986
Epoch 32/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4979
Epoch 33/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4965
Epoch 34/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4965
Epoch 35/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4960
Epoch 36/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4955
Epoch 37/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4952
Epoch 38/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4951
Epoch 39/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4950
Epoch 40/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4944
Epoch 41/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4941
Epoch 42/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4944
Epoch 43/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4936
Epoch 44/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4933
Epoch 45/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4930
Epoch 46/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4932
Epoch 47/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4927
```

```
Epoch 48/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4924
Epoch 49/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4922
Epoch 50/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4923
Epoch 51/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4916
Epoch 52/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4923
Epoch 53/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4915
Epoch 54/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4911
Epoch 55/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4913
Epoch 56/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4913
Epoch 57/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4912
Epoch 58/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4911
Epoch 59/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4906
Epoch 60/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4904
Epoch 61/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4908
Epoch 62/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4901
Epoch 63/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4907
Epoch 64/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4904
Epoch 65/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4900
Epoch 66/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4902
Epoch 67/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4899
Epoch 68/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4902
Epoch 69/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4901
Epoch 70/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4898
Epoch 71/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4897
Epoch 72/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4890
Epoch 73/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4897
Epoch 74/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4897
Epoch 75/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4897
Epoch 76/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4894
Epoch 77/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4896
Epoch 78/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4896
Epoch 79/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4890
Epoch 80/150
```

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350/350 [==============================] - 0s 1ms/step - loss: 0.4892
Epoch 81/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4892
Epoch 82/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4892
Epoch 83/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4892
Epoch 84/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4895
Epoch 85/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4891
Epoch 86/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4890
Epoch 87/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4892
Epoch 88/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4894
Epoch 89/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4892
Epoch 90/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4886
Epoch 91/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4883
Epoch 92/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4889
Epoch 93/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4894
Epoch 94/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4888
Epoch 95/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4890
Epoch 96/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4886
Epoch 97/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4886
Epoch 98/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4881
Epoch 99/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4891
Epoch 100/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4889
Epoch 101/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4878
Epoch 102/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4889
Epoch 103/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4886
Epoch 104/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4886
Epoch 105/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4890
Epoch 106/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4887
Epoch 107/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4887
Epoch 108/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4888
Epoch 109/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4884
Epoch 110/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4886
Epoch 111/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4884
Epoch 112/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4884
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Epoch 113/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4884
Epoch 114/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4889
Epoch 115/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4890
Epoch 116/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4885
Epoch 117/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4889
Epoch 118/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4890
Epoch 119/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4891
Epoch 120/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4891
Epoch 121/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4888
Epoch 122/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4888
Epoch 123/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4885
Epoch 124/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4883
Epoch 125/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4887
Epoch 126/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4889
Epoch 127/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4888
Epoch 128/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4887
Epoch 129/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4887
Epoch 130/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4884
Epoch 131/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4882
Epoch 132/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4889
Epoch 133/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4896
Epoch 134/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4885
Epoch 135/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4886
Epoch 136/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4885
Epoch 137/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4885
Epoch 138/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4887
Epoch 139/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4892
Epoch 140/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4887
Epoch 141/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4894
Epoch 142/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4887
Epoch 143/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4885
Epoch 144/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4889
Epoch 145/150
```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.4886
Epoch 146/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4887
Epoch 147/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4885
Epoch 148/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4889
Epoch 149/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4882
Epoch 150/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4888
```

_____
_____

Model Summary

_____
_____
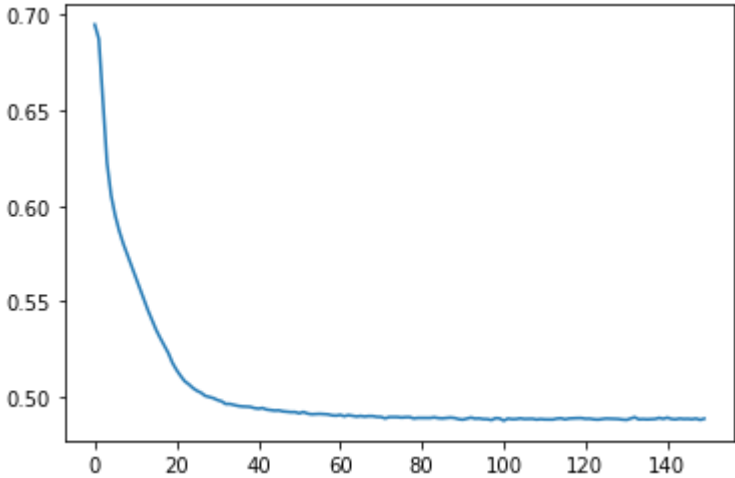
ROC Curve
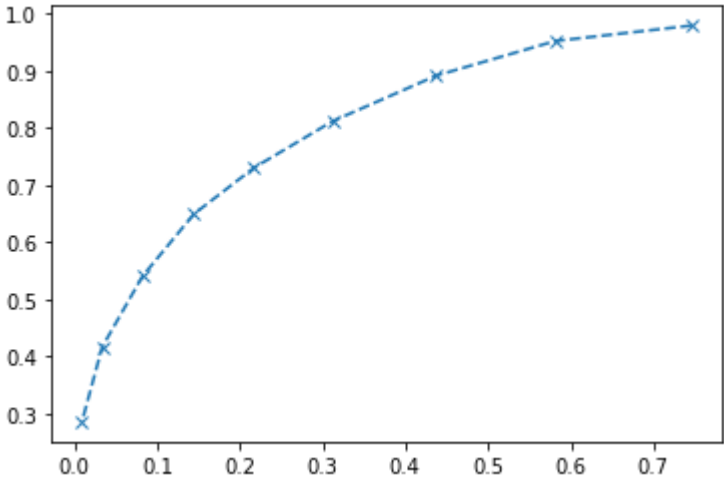
AUC ROC Score :   0.8443957843119463

In [63]:   eval_model(result_31[0], result_31[1], result_31[2], 0.5)

	precision	recall	f1-score	support
0	0.92	0.78	0.84	2373
1	0.47	0.73	0.57	627
accuracy			0.77	3000
macro avg	0.69	0.76	0.71	3000

weighted avg   0.82   0.77   0.79   3000

SMOTE

In [64]:
```python
over_sample = SMOTE(sampling_strategy='minority', random_state=1)
result_32 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 150, os=over_s
```

Model: "sequential_11"

Layer (type)	Output Shape	Param #
dense_68 (Dense)	(None, 3)	33
dense_69 (Dense)	(None, 3)	12
dense_70 (Dense)	(None, 3)	12
dense_71 (Dense)	(None, 1)	4

Total params: 61
Trainable params: 61
Non-trainable params: 0

Building NN Model

```
Epoch 1/150
350/350 [==============================] - 0s 947us/step - loss: 0.6881
Epoch 2/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6575
Epoch 3/150
350/350 [==============================] - 0s 968us/step - loss: 0.6209
Epoch 4/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6009
Epoch 5/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5882
Epoch 6/150
350/350 [==============================] - 0s 980us/step - loss: 0.5780
Epoch 7/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5699
Epoch 8/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5643
Epoch 9/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5590
Epoch 10/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5546
Epoch 11/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5519
Epoch 12/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5492
Epoch 13/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5475
Epoch 14/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5459
Epoch 15/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5445
Epoch 16/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5434
Epoch 17/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5417
```

```
Epoch 18/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5406
Epoch 19/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5394
Epoch 20/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5380
Epoch 21/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5367
Epoch 22/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5356
Epoch 23/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5344
Epoch 24/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5332
Epoch 25/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5327
Epoch 26/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5322
Epoch 27/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5312
Epoch 28/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5301
Epoch 29/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5295
Epoch 30/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5288
Epoch 31/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5281
Epoch 32/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5275
Epoch 33/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5270
Epoch 34/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5259
Epoch 35/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5250
Epoch 36/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5241
Epoch 37/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5238
Epoch 38/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5227
Epoch 39/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5221
Epoch 40/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5209
Epoch 41/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5212
Epoch 42/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5204
Epoch 43/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5200
Epoch 44/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5197
Epoch 45/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5199
Epoch 46/150
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Epoch 47/150
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Epoch 48/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5189
Epoch 49/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5182
Epoch 50/150
```

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350/350 [==============================] - 0s 1ms/step - loss: 0.5183
Epoch 51/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5182
Epoch 52/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5178
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Epoch 58/150
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Epoch 62/150
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Epoch 63/150
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Epoch 79/150
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Epoch 80/150
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Epoch 81/150
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Epoch 82/150
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Epoch 83/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5147
Epoch 84/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5144
Epoch 85/150
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Epoch 110/150
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Epoch 111/150
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Epoch 113/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5130
Epoch 114/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5130
Epoch 115/150
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350/350 [==============================] - 0s 1ms/step - loss: 0.5129
Epoch 116/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5135
Epoch 117/150
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Epoch 118/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5127
Epoch 119/150
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Epoch 123/150
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Epoch 124/150
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Epoch 125/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5130
Epoch 126/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5131
Epoch 127/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5128
Epoch 128/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5132
Epoch 129/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5126
Epoch 130/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5124
Epoch 131/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5121
Epoch 132/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5123
Epoch 133/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5128
Epoch 134/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5121
Epoch 135/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5127
Epoch 136/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5126
Epoch 137/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5128
Epoch 138/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5124
Epoch 139/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5124
Epoch 140/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5122
Epoch 141/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5126
Epoch 142/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5127
Epoch 143/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5118
Epoch 144/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5125
Epoch 145/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5125
Epoch 146/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5120
Epoch 147/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5124
```

```
Epoch 148/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5126
Epoch 149/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5120
Epoch 150/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5126
```

Model Summary
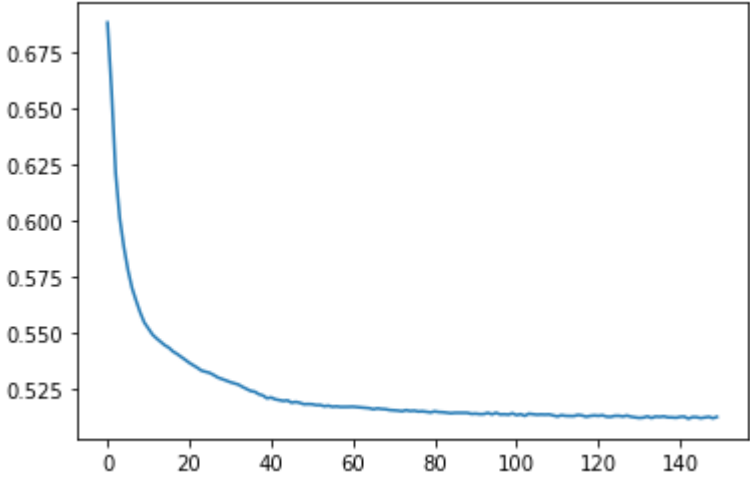
ROC Curve
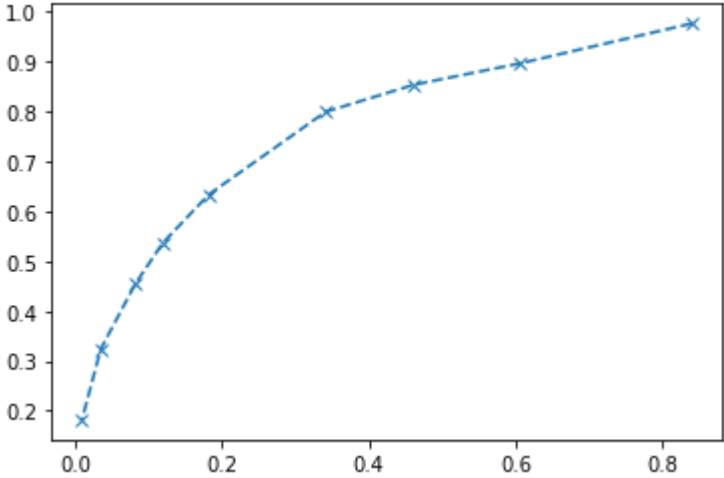
AUC ROC Score : 0.8013376159626743

In [65]: `eval_model(result_32[0], result_32[1], result_32[2], 0.4)`

```
              precision    recall  f1-score   support

           0       0.93      0.66      0.77      2373
           1       0.38      0.80      0.52       627

    accuracy                           0.69      3000
   macro avg       0.65      0.73      0.64      3000
weighted avg       0.81      0.69      0.72      3000
```

Assumptions

In this iteration, we followed up after creating models with the lowest complexity. We slightly increased the complexity from one hidden layer to two hidden layers. The Recall scores seem to have bettered. SMOTE scored better.

> **0.67, 0.76 - Base (0.3, 0.2)**
>
> **0.73 - RandomOverSampler (0.5)**
>
> **0.80 - SMOTE (0.4)**

NN Models - Low Complexity v1.2

The models in this iteration will have three hidden layers.

Base Model

```
In [66]:   nodes = [3,5,3]
           result_40 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 50)
```

```
Model: "sequential_12"
_____
Layer (type)                 Output Shape              Param #
=================================================================
dense_72 (Dense)             (None, 3)                 33
_____
dense_73 (Dense)             (None, 3)                 12
_____
dense_74 (Dense)             (None, 5)                 20
_____
dense_75 (Dense)             (None, 3)                 18
_____
dense_76 (Dense)             (None, 1)                 4
=================================================================
Total params: 87
Trainable params: 87
Non-trainable params: 0
_____


Building NN Model

Epoch 1/50
219/219 [==============================] - 0s 906us/step - loss: 0.6625
Epoch 2/50
219/219 [==============================] - 0s 975us/step - loss: 0.5416
Epoch 3/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4858
Epoch 4/50
219/219 [==============================] - 0s 984us/step - loss: 0.4636
Epoch 5/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4501
Epoch 6/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4370
Epoch 7/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4258
Epoch 8/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4175
```

```
Epoch 9/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4117
Epoch 10/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4063
Epoch 11/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4019
Epoch 12/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3970
Epoch 13/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3930
Epoch 14/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3896
Epoch 15/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3866
Epoch 16/50
219/219 [==============================] - 0s 993us/step - loss: 0.3837
Epoch 17/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3814
Epoch 18/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3790
Epoch 19/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3782
Epoch 20/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3762
Epoch 21/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3749
Epoch 22/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3737
Epoch 23/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3729
Epoch 24/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3721
Epoch 25/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3719
Epoch 26/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3708
Epoch 27/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3704
Epoch 28/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3700
Epoch 29/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3689
Epoch 30/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3693
Epoch 31/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3686
Epoch 32/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3684
Epoch 33/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3682
Epoch 34/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3683
Epoch 35/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3673
Epoch 36/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3672
Epoch 37/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3674
Epoch 38/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3672
Epoch 39/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3666
Epoch 40/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3666
Epoch 41/50
```

```
219/219 [==============================] - 0s 1ms/step - loss: 0.3668
Epoch 42/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3661
Epoch 43/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3659
Epoch 44/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3664
Epoch 45/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3663
Epoch 46/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3661
Epoch 47/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3664
Epoch 48/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3662
Epoch 49/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3659
Epoch 50/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3658
```

_____

Model Summary

_____
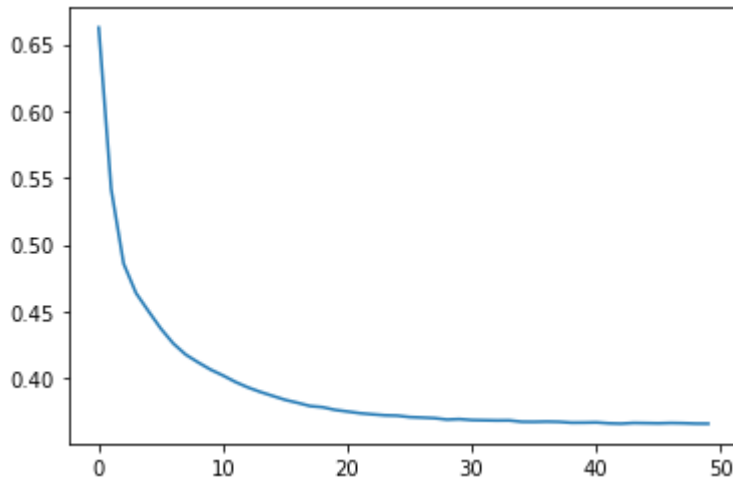
ROC Curve
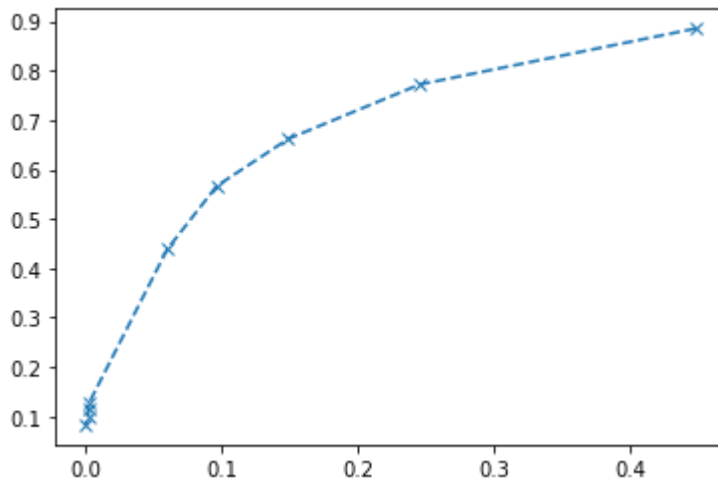
AUC ROC Score : 0.8397475318760833

```
In [67]:    eval_model(result_40[0], result_40[1], result_40[2], 0.3)
```

	precision	recall	f1-score	support
0	0.91	0.85	0.88	2373
1	0.54	0.66	0.59	627
accuracy			0.81	3000
macro avg	0.72	0.76	0.74	3000
weighted avg	0.83	0.81	0.82	3000

RandomOverSampler

In [68]:
```
over_sample = RandomOverSampler(sampling_strategy='minority', random_state=1)
result_41 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 150, os=over_s
```

Model: "sequential_13"

Layer (type)	Output Shape	Param #
dense_77 (Dense)	(None, 3)	33
dense_78 (Dense)	(None, 3)	12
dense_79 (Dense)	(None, 5)	20
dense_80 (Dense)	(None, 3)	18
dense_81 (Dense)	(None, 1)	4

Total params: 87
Trainable params: 87
Non-trainable params: 0

Building NN Model

```
Epoch 1/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6661
Epoch 2/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6056
Epoch 3/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5878
Epoch 4/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5810
Epoch 5/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5774
Epoch 6/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5750
Epoch 7/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5725
Epoch 8/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5699
Epoch 9/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5674
Epoch 10/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5640
Epoch 11/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5605
Epoch 12/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5571
Epoch 13/150
```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.5534
Epoch 14/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5504
Epoch 15/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5483
Epoch 16/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5460
Epoch 17/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5433
Epoch 18/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5397
Epoch 19/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5370
Epoch 20/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5345
Epoch 21/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5334
Epoch 22/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5322
Epoch 23/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5310
Epoch 24/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5300
Epoch 25/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5290
Epoch 26/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5281
Epoch 27/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5270
Epoch 28/150
350/350 [==============================] - 1s 1ms/step - loss: 0.5258
Epoch 29/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5253
Epoch 30/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5245
Epoch 31/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5238
Epoch 32/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5230
Epoch 33/150
350/350 [==============================] - ETA: 0s - loss: 0.520 - 0s 1ms/step - loss:
0.5223
Epoch 34/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5215
Epoch 35/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5212
Epoch 36/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5206
Epoch 37/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5203
Epoch 38/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5197
Epoch 39/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5197
Epoch 40/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5188
Epoch 41/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5187
Epoch 42/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5185
Epoch 43/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5179
Epoch 44/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5176
Epoch 45/150
```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.5178
Epoch 46/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5166
Epoch 47/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5158
Epoch 48/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5155A: 0s - loss: 0
Epoch 49/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5153
Epoch 50/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5148
Epoch 51/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5151
Epoch 52/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5144
Epoch 53/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5141
Epoch 54/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5136
Epoch 55/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5140
Epoch 56/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5133
Epoch 57/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5134
Epoch 58/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5130
Epoch 59/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5128
Epoch 60/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5115
Epoch 61/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5114
Epoch 62/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5116
Epoch 63/150
350/350 [==============================] - 1s 1ms/step - loss: 0.5115
Epoch 64/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5110
Epoch 65/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5106
Epoch 66/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5104
Epoch 67/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5105
Epoch 68/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5107
Epoch 69/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5106
Epoch 70/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5101
Epoch 71/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5105
Epoch 72/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5099
Epoch 73/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5098
Epoch 74/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5097
Epoch 75/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5092
Epoch 76/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5095
Epoch 77/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5092
```

```
Epoch 78/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5091
Epoch 79/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5095
Epoch 80/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5091
Epoch 81/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5094
Epoch 82/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5092
Epoch 83/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5087
Epoch 84/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5093
Epoch 85/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5091
Epoch 86/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5087
Epoch 87/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5086
Epoch 88/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5085
Epoch 89/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5087
Epoch 90/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5084
Epoch 91/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5080
Epoch 92/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5083
Epoch 93/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5087
Epoch 94/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5092
Epoch 95/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5084
Epoch 96/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5080
Epoch 97/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5084
Epoch 98/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5083
Epoch 99/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5078
Epoch 100/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5087
Epoch 101/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5085
Epoch 102/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5080
Epoch 103/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5076
Epoch 104/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5083
Epoch 105/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5083
Epoch 106/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5078
Epoch 107/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5078
Epoch 108/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5084
Epoch 109/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5080
Epoch 110/150
```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.5082
Epoch 111/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5083
Epoch 112/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5083
Epoch 113/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5077
Epoch 114/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5082
Epoch 115/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5077
Epoch 116/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5079
Epoch 117/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5076
Epoch 118/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5075
Epoch 119/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5074
Epoch 120/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5076
Epoch 121/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5072
Epoch 122/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5069
Epoch 123/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5076
Epoch 124/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5069
Epoch 125/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5072
Epoch 126/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5070
Epoch 127/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5064
Epoch 128/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5070
Epoch 129/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5073
Epoch 130/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5063
Epoch 131/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5070
Epoch 132/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5063
Epoch 133/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5067
Epoch 134/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5071
Epoch 135/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5066
Epoch 136/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5066
Epoch 137/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5072
Epoch 138/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5071
Epoch 139/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5064
Epoch 140/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5061
Epoch 141/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5060
Epoch 142/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5062
```

```
Epoch 143/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5066
Epoch 144/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5067
Epoch 145/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5072
Epoch 146/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5062
Epoch 147/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5072
Epoch 148/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5068
Epoch 149/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5061
Epoch 150/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5066
```

Model Summary
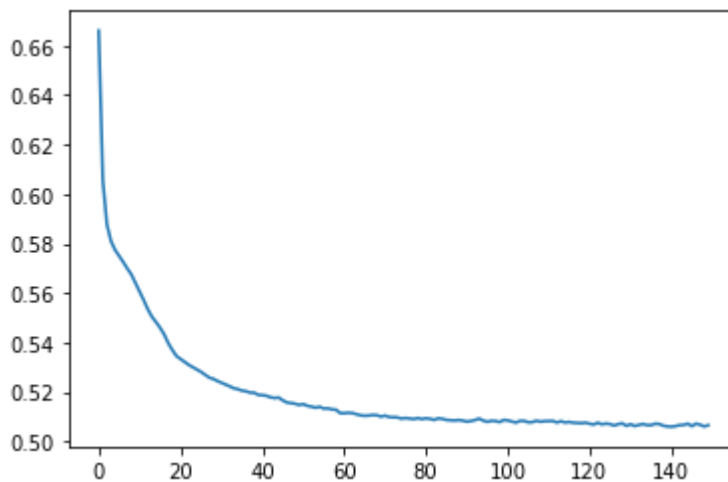
ROC Curve
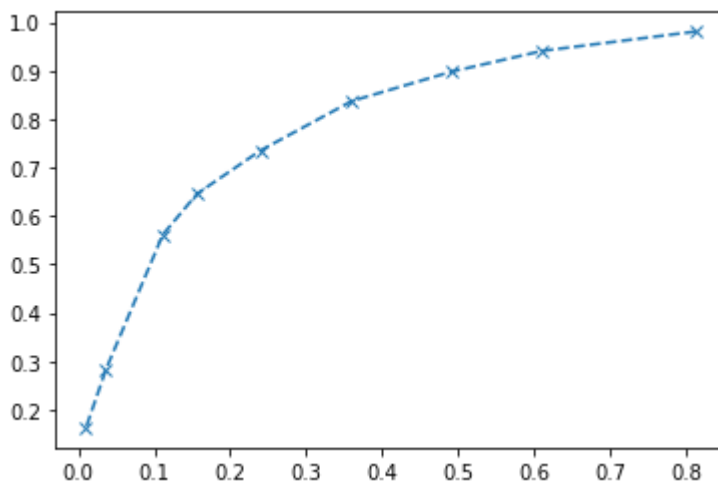
AUC ROC Score : 0.8249596235157484

In [69]: `eval_model(result_41[0], result_41[1], result_41[2], 0.5)`

                    precision   recall f1-score   support

	0	0.92	0.76	0.83	2373
	1	0.45	0.74	0.56	627
accuracy				0.76	3000
macro avg		0.68	0.75	0.69	3000
weighted avg		0.82	0.76	0.77	3000

SMOTE

In [70]:
```python
over_sample = SMOTE(sampling_strategy='minority', random_state=1)
result_42 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 150, os=over_s
```

Model: "sequential_14"

```
_____
Layer (type)                 Output Shape              Param #
===============================================================
dense_82 (Dense)             (None, 3)                 33
_____
dense_83 (Dense)             (None, 3)                 12
_____
dense_84 (Dense)             (None, 5)                 20
_____
dense_85 (Dense)             (None, 3)                 18
_____
dense_86 (Dense)             (None, 1)                 4
===============================================================
Total params: 87
Trainable params: 87
Non-trainable params: 0
_____


Building NN Model

Epoch 1/150
350/350 [==============================] - 0s 975us/step - loss: 0.6936
Epoch 2/150
350/350 [==============================] - 0s 980us/step - loss: 0.6828
Epoch 3/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6148
Epoch 4/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5893
Epoch 5/150
350/350 [==============================] - 0s 940us/step - loss: 0.5766
Epoch 6/150
350/350 [==============================] - 0s 946us/step - loss: 0.5671
Epoch 7/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5587
Epoch 8/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5504
Epoch 9/150
350/350 [==============================] - 0s 986us/step - loss: 0.5419
Epoch 10/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5335
Epoch 11/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5273
Epoch 12/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5225
Epoch 13/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5196
Epoch 14/150
```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.5179
Epoch 15/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5159
Epoch 16/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5155
Epoch 17/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5141
Epoch 18/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5136
Epoch 19/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5124
Epoch 20/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5119
Epoch 21/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5114
Epoch 22/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5111
Epoch 23/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5105
Epoch 24/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5099
Epoch 25/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5090
Epoch 26/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5083
Epoch 27/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5081
Epoch 28/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5072
Epoch 29/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5064
Epoch 30/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5058
Epoch 31/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5052
Epoch 32/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5042
Epoch 33/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5026
Epoch 34/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5013
Epoch 35/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5003
Epoch 36/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4991
Epoch 37/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4973
Epoch 38/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4963
Epoch 39/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4957
Epoch 40/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4946
Epoch 41/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4935
Epoch 42/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4926
Epoch 43/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4915
Epoch 44/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4906
Epoch 45/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4895
Epoch 46/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4887
```

```
                 Epoch 47/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4884
                 Epoch 48/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4882
                 Epoch 49/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4871
                 Epoch 50/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4874
                 Epoch 51/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4869
                 Epoch 52/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4868
                 Epoch 53/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4864
                 Epoch 54/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4864
                 Epoch 55/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4860
                 Epoch 56/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4860
                 Epoch 57/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4861
                 Epoch 58/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4863
                 Epoch 59/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4852
                 Epoch 60/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4851
                 Epoch 61/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4853
                 Epoch 62/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4855
                 Epoch 63/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4854
                 Epoch 64/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4852
                 Epoch 65/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4849
                 Epoch 66/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4849
                 Epoch 67/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4852
                 Epoch 68/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4848
                 Epoch 69/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4852
                 Epoch 70/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4852
                 Epoch 71/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4854
                 Epoch 72/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4847
                 Epoch 73/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4851
                 Epoch 74/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4848
                 Epoch 75/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4851
                 Epoch 76/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4848
                 Epoch 77/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4851
                 Epoch 78/150
                 350/350 [==============================] - 0s 1ms/step - loss: 0.4852
                 Epoch 79/150
```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.4850
Epoch 80/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4846
Epoch 81/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4846
Epoch 82/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4846
Epoch 83/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4852
Epoch 84/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4846
Epoch 85/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4850
Epoch 86/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4849
Epoch 87/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4848
Epoch 88/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4846
Epoch 89/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4849
Epoch 90/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4849
Epoch 91/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4848
Epoch 92/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4848
Epoch 93/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4846
Epoch 94/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4846
Epoch 95/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4852
Epoch 96/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4847
Epoch 97/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4851
Epoch 98/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4846
Epoch 99/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4845
Epoch 100/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4845
Epoch 101/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4849
Epoch 102/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4848
Epoch 103/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4844
Epoch 104/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4848
Epoch 105/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4844
Epoch 106/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4846
Epoch 107/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4846
Epoch 108/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4844
Epoch 109/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4845
Epoch 110/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4852
Epoch 111/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4853
```

```
Epoch 112/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4851
Epoch 113/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4849
Epoch 114/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4846
Epoch 115/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4844
Epoch 116/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4845
Epoch 117/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4851
Epoch 118/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4849
Epoch 119/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4848
Epoch 120/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4845
Epoch 121/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4843
Epoch 122/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4844
Epoch 123/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4843
Epoch 124/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4845
Epoch 125/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4844
Epoch 126/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4847
Epoch 127/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4843
Epoch 128/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4846
Epoch 129/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4846
Epoch 130/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4843
Epoch 131/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4843
Epoch 132/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4840
Epoch 133/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4841
Epoch 134/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4836
Epoch 135/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4839
Epoch 136/150
350/350 [==============================] - 1s 2ms/step - loss: 0.4840
Epoch 137/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4846
Epoch 138/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4841
Epoch 139/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4838
Epoch 140/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4838
Epoch 141/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4838
Epoch 142/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4836
Epoch 143/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4840
Epoch 144/150
```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.4834
Epoch 145/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4841
Epoch 146/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4836
Epoch 147/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4836
Epoch 148/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4833
Epoch 149/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4833
Epoch 150/150
350/350 [==============================] - 0s 1ms/step - loss: 0.4831
```

_____
_____

Model Summary

_____
_____
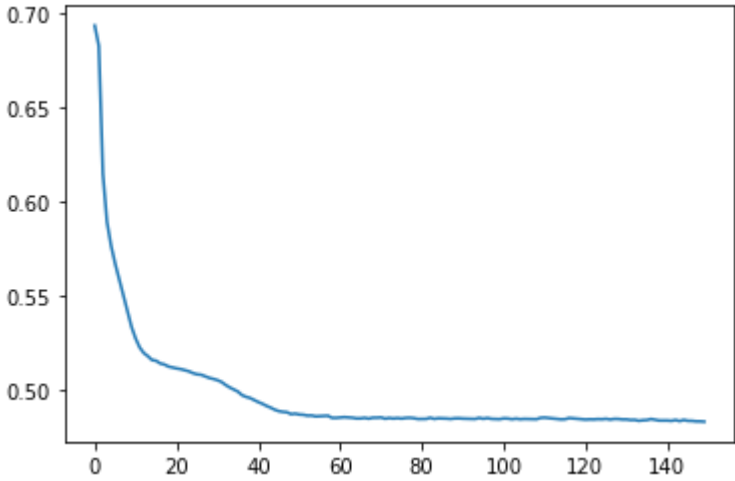
ROC Curve
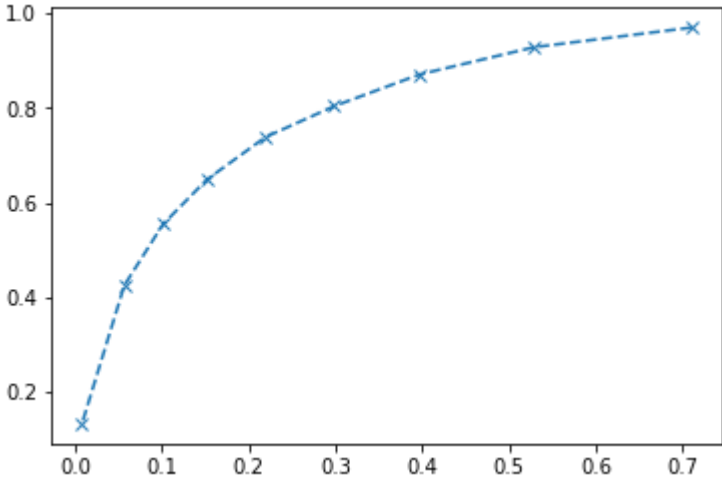
AUC ROC Score : 0.8364770870592948

In [71]: `eval_model(result_42[0], result_42[1], result_42[2], 0.5)`

	precision	recall	f1-score	support
0	0.92	0.78	0.84	2373
1	0.47	0.74	0.58	627

```
        accuracy                          0.77      3000
       macro avg       0.69     0.76      0.71      3000
    weighted avg       0.83     0.77      0.79      3000
```

Assumptions

Once again, we slightly increased the complexity from two hidden layer to three hidden layers. RandomOverSampler and SMOTE scored the same.

0.66 - Base (0.3)

0.74 - RandomOverSampler (0.5)

0.74 - SMOTE (0.5)

Models with Dropout

We will proceed with building the same previous models, however, here we will add dropout to see if we can get better results.

NN Models - Medium Complexity v2.0

The first models will be built with a medium amount of complexity, with dropout.

Base Model

```
In [72]:  nodes = [5,6,0.5,8,0.5,6,0.5,5]
          result_01 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 50, 100)
```

Model: "sequential_15"

Layer (type)	Output Shape	Param #
dense_87 (Dense)	(None, 3)	33
dense_88 (Dense)	(None, 5)	20
dense_89 (Dense)	(None, 6)	36
dropout (Dropout)	(None, 6)	0
dense_90 (Dense)	(None, 8)	56
dropout_1 (Dropout)	(None, 8)	0
dense_91 (Dense)	(None, 6)	54
dropout_2 (Dropout)	(None, 6)	0
dense_92 (Dense)	(None, 5)	35
dense_93 (Dense)	(None, 1)	6

```
Total params: 240
Trainable params: 240
Non-trainable params: 0
```
_____

Building NN Model

```
Epoch 1/50
70/70 [==============================] - 0s 1ms/step - loss: 0.7186
Epoch 2/50
70/70 [==============================] - 0s 1ms/step - loss: 0.6437
Epoch 3/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5980
Epoch 4/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5595
Epoch 5/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5364
Epoch 6/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5258
Epoch 7/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5173
Epoch 8/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5160
Epoch 9/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5105
Epoch 10/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5091
Epoch 11/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5092
Epoch 12/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5070
Epoch 13/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5047
Epoch 14/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5051
Epoch 15/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5049
Epoch 16/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5049
Epoch 17/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5034
Epoch 18/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5039
Epoch 19/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5033
Epoch 20/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5033
Epoch 21/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5029
Epoch 22/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5032
Epoch 23/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5022
Epoch 24/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5025
Epoch 25/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5027
Epoch 26/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5022
Epoch 27/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5030
Epoch 28/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5025
Epoch 29/50
```

```
70/70 [==============================] - 0s 1ms/step - loss: 0.5029
Epoch 30/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5025
Epoch 31/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5022
Epoch 32/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5023
Epoch 33/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5017
Epoch 34/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5016
Epoch 35/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4997
Epoch 36/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4947
Epoch 37/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4914
Epoch 38/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4863
Epoch 39/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4845
Epoch 40/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4843
Epoch 41/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4827
Epoch 42/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4850
Epoch 43/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4751
Epoch 44/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4774
Epoch 45/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4762
Epoch 46/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4767
Epoch 47/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4737
Epoch 48/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4760
Epoch 49/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4723
Epoch 50/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4686
```

_____
_____

Model Summary

_____

_____
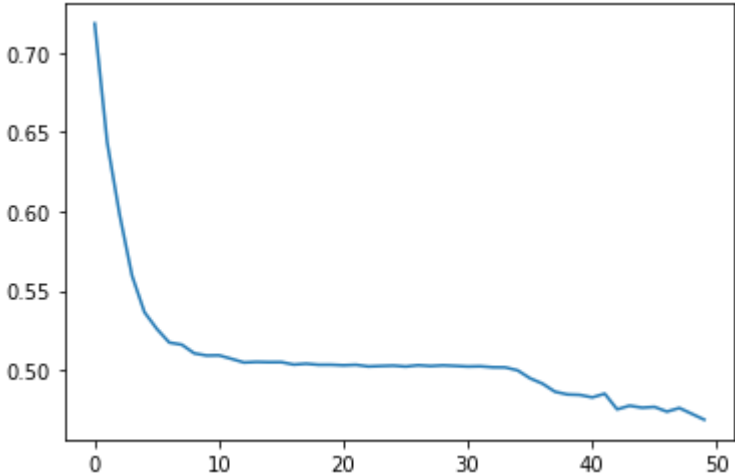
ROC Curve
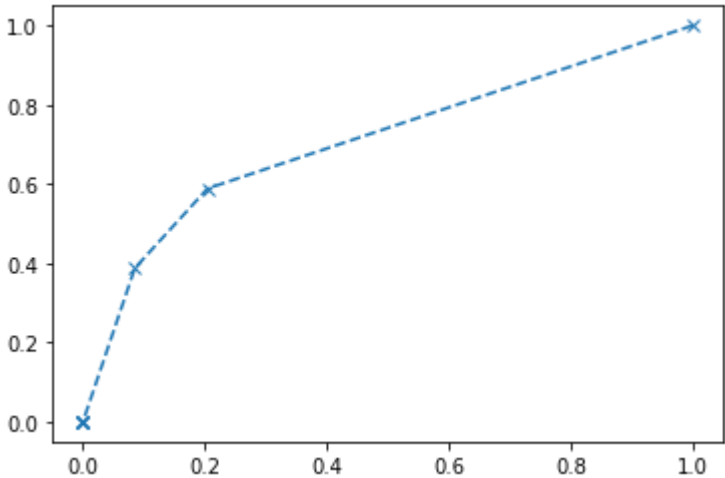
AUC ROC Score :   0.7459141283081665

In [73]:   `eval_model(result_01[0], result_01[1], result_01[2], 0.3)`

	precision	recall	f1-score	support
0	0.85	0.91	0.88	2373
1	0.55	0.39	0.45	627
accuracy			0.80	3000
macro avg	0.70	0.65	0.67	3000
weighted avg	0.79	0.80	0.79	3000

In [74]:   `eval_model(result_01[0], result_01[1], result_01[2], 0.2)`

	precision	recall	f1-score	support
0	0.88	0.80	0.84	2373
1	0.43	0.59	0.50	627
accuracy			0.75	3000
macro avg	0.66	0.69	0.67	3000
weighted avg	0.79	0.75	0.77	3000

RandomOverSampler

In [75]:   `over_sample = RandomOverSampler(sampling_strategy="minority", random_state=1)`

In [76]:   `result_02 = nn_model(X, y, nodes, "relu", "sgd", "binary_crossentropy", 150, 100, over_`

Model: "sequential_16"

Layer (type)	Output Shape	Param #
dense_94 (Dense)	(None, 3)	33
dense_95 (Dense)	(None, 5)	20
dense_96 (Dense)	(None, 6)	36

```
_____
dropout_3 (Dropout)        (None, 6)              0
_____
dense_97 (Dense)           (None, 8)              56
_____
dropout_4 (Dropout)        (None, 8)              0
_____
dense_98 (Dense)           (None, 6)              54
_____
dropout_5 (Dropout)        (None, 6)              0
_____
dense_99 (Dense)           (None, 5)              35
_____
dense_100 (Dense)          (None, 1)              6
=====================================================
Total params: 240
Trainable params: 240
Non-trainable params: 0
_____


Building NN Model

Epoch 1/150
112/112 [==============================] - 0s 1ms/step - loss: 0.7007
Epoch 2/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6989
Epoch 3/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6969
Epoch 4/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6969
Epoch 5/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6947
Epoch 6/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6946
Epoch 7/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6945
Epoch 8/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6942
Epoch 9/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6937
Epoch 10/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6932
Epoch 11/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6940
Epoch 12/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6933
Epoch 13/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6925
Epoch 14/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6934
Epoch 15/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6930
Epoch 16/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6933
Epoch 17/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6938
Epoch 18/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6932
Epoch 19/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6932
Epoch 20/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6931
Epoch 21/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6925
```

```
Epoch 22/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6928
Epoch 23/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6928
Epoch 24/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6926
Epoch 25/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6920
Epoch 26/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6927
Epoch 27/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6931
Epoch 28/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6924
Epoch 29/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6925
Epoch 30/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6931
Epoch 31/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6930
Epoch 32/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6922
Epoch 33/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6925
Epoch 34/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6922
Epoch 35/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6920
Epoch 36/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6920
Epoch 37/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6918
Epoch 38/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6913
Epoch 39/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6918
Epoch 40/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6919
Epoch 41/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6921
Epoch 42/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6920
Epoch 43/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6918
Epoch 44/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6917
Epoch 45/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6912
Epoch 46/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6912
Epoch 47/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6917
Epoch 48/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6920
Epoch 49/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6917
Epoch 50/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6912
Epoch 51/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6908
Epoch 52/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6911
Epoch 53/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6910
Epoch 54/150
```

```
112/112 [==============================] - 0s 1ms/step - loss: 0.6910
Epoch 55/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6902
Epoch 56/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6905
Epoch 57/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6904
Epoch 58/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6902
Epoch 59/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6899
Epoch 60/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6913
Epoch 61/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6897
Epoch 62/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6892
Epoch 63/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6890
Epoch 64/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6893
Epoch 65/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6880
Epoch 66/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6888
Epoch 67/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6891
Epoch 68/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6880
Epoch 69/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6890
Epoch 70/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6889
Epoch 71/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6874
Epoch 72/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6871
Epoch 73/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6874
Epoch 74/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6853
Epoch 75/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6870
Epoch 76/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6851
Epoch 77/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6868
Epoch 78/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6848
Epoch 79/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6851
Epoch 80/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6859
Epoch 81/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6839
Epoch 82/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6848
Epoch 83/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6837
Epoch 84/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6833
Epoch 85/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6841
Epoch 86/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6823
```

```
Epoch 87/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6823
Epoch 88/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6821
Epoch 89/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6822
Epoch 90/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6814
Epoch 91/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6794
Epoch 92/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6804
Epoch 93/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6788
Epoch 94/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6784
Epoch 95/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6810
Epoch 96/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6802
Epoch 97/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6783
Epoch 98/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6778
Epoch 99/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6796
Epoch 100/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6787
Epoch 101/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6786
Epoch 102/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6783
Epoch 103/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6763
Epoch 104/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6751
Epoch 105/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6745
Epoch 106/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6746
Epoch 107/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6752
Epoch 108/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6737
Epoch 109/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6718
Epoch 110/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6748
Epoch 111/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6704
Epoch 112/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6711
Epoch 113/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6724
Epoch 114/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6717
Epoch 115/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6718
Epoch 116/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6680
Epoch 117/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6674
Epoch 118/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6663
Epoch 119/150
```

```
112/112 [==============================] - 0s 1ms/step - loss: 0.6669
Epoch 120/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6659
Epoch 121/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6689
Epoch 122/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6711
Epoch 123/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6654
Epoch 124/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6648
Epoch 125/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6654
Epoch 126/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6647
Epoch 127/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6682
Epoch 128/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6647
Epoch 129/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6634
Epoch 130/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6639
Epoch 131/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6634
Epoch 132/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6614
Epoch 133/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6615
Epoch 134/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6567
Epoch 135/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6596
Epoch 136/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6607
Epoch 137/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6601
Epoch 138/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6584
Epoch 139/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6586
Epoch 140/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6620
Epoch 141/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6568
Epoch 142/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6632
Epoch 143/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6575
Epoch 144/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6577
Epoch 145/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6555
Epoch 146/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6573
Epoch 147/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6557
Epoch 148/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6578
Epoch 149/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6597
Epoch 150/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6560
```

_____

Model Summary
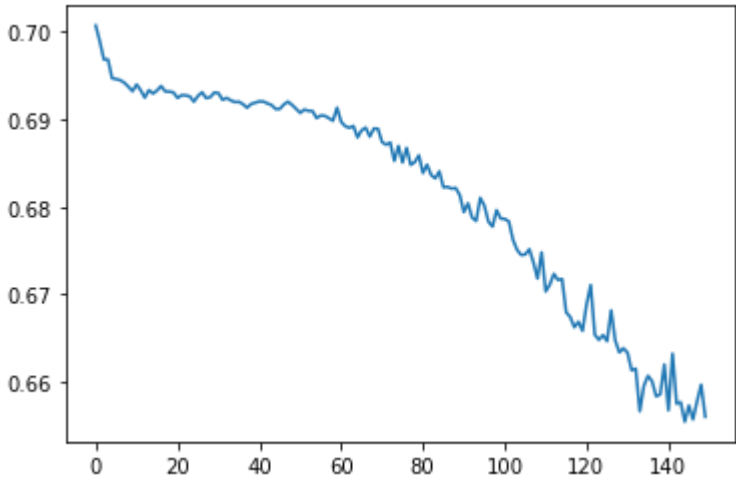
ROC Curve
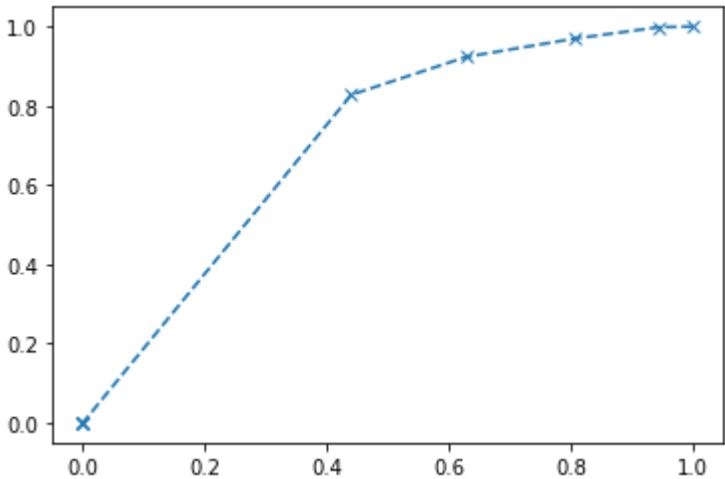
AUC ROC Score : 0.7420189653538513

In [77]: ```
eval_model(result_02[0], result_02[1], result_02[2], 0.5)
```

```
              precision    recall  f1-score   support

           0       0.92      0.56      0.70      2373
           1       0.33      0.83      0.47       627

    accuracy                           0.62      3000
   macro avg       0.63      0.69      0.59      3000
weighted avg       0.80      0.62      0.65      3000
```

SMOTE

In [78]: ```
over_sample = SMOTE(sampling_strategy="minority", random_state=1)
```

In [79]: ```
result_03 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 150, 100, over_
```

Model: "sequential_17"

```
Layer (type)                Output Shape              Param #
=================================================================
dense_101 (Dense)           (None, 3)                 33
_____
dense_102 (Dense)           (None, 5)                 20
_____
dense_103 (Dense)           (None, 6)                 36
_____
dropout_6 (Dropout)         (None, 6)                 0
_____
dense_104 (Dense)           (None, 8)                 56
_____
dropout_7 (Dropout)         (None, 8)                 0
_____
dense_105 (Dense)           (None, 6)                 54
_____
dropout_8 (Dropout)         (None, 6)                 0
_____
dense_106 (Dense)           (None, 5)                 35
_____
dense_107 (Dense)           (None, 1)                 6
=================================================================
Total params: 240
Trainable params: 240
Non-trainable params: 0
_____


Building NN Model

Epoch 1/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6929
Epoch 2/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6904
Epoch 3/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6838
Epoch 4/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6718
Epoch 5/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6618
Epoch 6/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6544
Epoch 7/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6486
Epoch 8/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6471
Epoch 9/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6495
Epoch 10/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6447
Epoch 11/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6444
Epoch 12/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6422
Epoch 13/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6430
Epoch 14/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6411
Epoch 15/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6371
Epoch 16/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6357
Epoch 17/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6324
Epoch 18/150
```

```
112/112 [==============================] - 0s 2ms/step - loss: 0.6324
Epoch 19/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6321
Epoch 20/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6258
Epoch 21/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6244
Epoch 22/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6226
Epoch 23/150
112/112 [==============================] - 0s 2ms/step - loss: 0.6173
Epoch 24/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6223
Epoch 25/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6137
Epoch 26/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6133
Epoch 27/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6112
Epoch 28/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6084
Epoch 29/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6049
Epoch 30/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6058
Epoch 31/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6062
Epoch 32/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6070
Epoch 33/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6012
Epoch 34/150
112/112 [==============================] - 0s 1ms/step - loss: 0.6019
Epoch 35/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5999
Epoch 36/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5998
Epoch 37/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5931
Epoch 38/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5949
Epoch 39/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5944
Epoch 40/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5870
Epoch 41/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5868
Epoch 42/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5855
Epoch 43/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5859
Epoch 44/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5872
Epoch 45/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5895
Epoch 46/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5839
Epoch 47/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5792
Epoch 48/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5780
Epoch 49/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5805
Epoch 50/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5841
```

```
Epoch 51/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5826
Epoch 52/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5770
Epoch 53/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5756
Epoch 54/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5779
Epoch 55/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5783
Epoch 56/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5690
Epoch 57/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5732
Epoch 58/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5743
Epoch 59/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5724
Epoch 60/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5705
Epoch 61/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5694
Epoch 62/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5688
Epoch 63/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5738
Epoch 64/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5694
Epoch 65/150
112/112 [==============================] - 0s 3ms/step - loss: 0.5711
Epoch 66/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5718
Epoch 67/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5734
Epoch 68/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5689
Epoch 69/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5672
Epoch 70/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5674
Epoch 71/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5705
Epoch 72/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5717
Epoch 73/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5668
Epoch 74/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5672
Epoch 75/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5638
Epoch 76/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5673
Epoch 77/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5670
Epoch 78/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5632
Epoch 79/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5657
Epoch 80/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5627
Epoch 81/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5659
Epoch 82/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5685
Epoch 83/150
```

```
112/112 [==============================] - 0s 1ms/step - loss: 0.5675
Epoch 84/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5663
Epoch 85/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5662
Epoch 86/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5631
Epoch 87/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5628
Epoch 88/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5656
Epoch 89/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5646
Epoch 90/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5679
Epoch 91/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5687
Epoch 92/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5622
Epoch 93/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5676
Epoch 94/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5636
Epoch 95/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5701
Epoch 96/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5653
Epoch 97/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5631
Epoch 98/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5672
Epoch 99/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5679
Epoch 100/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5590
Epoch 101/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5626
Epoch 102/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5639
Epoch 103/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5635
Epoch 104/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5615
Epoch 105/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5611
Epoch 106/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5640
Epoch 107/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5663
Epoch 108/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5591
Epoch 109/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5615
Epoch 110/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5634
Epoch 111/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5673
Epoch 112/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5606
Epoch 113/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5574
Epoch 114/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5656
Epoch 115/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5609
```

```
Epoch 116/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5642
Epoch 117/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5639
Epoch 118/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5671
Epoch 119/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5679
Epoch 120/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5659
Epoch 121/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5599
Epoch 122/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5637
Epoch 123/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5591
Epoch 124/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5620A: 0s - loss: 0.56
Epoch 125/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5608
Epoch 126/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5615
Epoch 127/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5612
Epoch 128/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5681
Epoch 129/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5645
Epoch 130/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5604
Epoch 131/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5610
Epoch 132/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5615
Epoch 133/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5621
Epoch 134/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5675
Epoch 135/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5614
Epoch 136/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5626
Epoch 137/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5597
Epoch 138/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5602
Epoch 139/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5650
Epoch 140/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5658
Epoch 141/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5603
Epoch 142/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5565
Epoch 143/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5581
Epoch 144/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5620
Epoch 145/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5658
Epoch 146/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5650A: 0s - loss: 0.565
Epoch 147/150
112/112 [==============================] - 0s 1ms/step - loss: 0.5666
Epoch 148/150
```

```
112/112 [==============================] - 0s 1ms/step - loss: 0.5622
Epoch 149/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5688
Epoch 150/150
112/112 [==============================] - 0s 2ms/step - loss: 0.5651
```

_____
_____

Model Summary

_____
_____

ROC Curve

AUC ROC Score :   0.8045401785504254

In [80]: `eval_model(result_03[0], result_03[1], result_03[2], 0.6)`

```
              precision    recall  f1-score   support
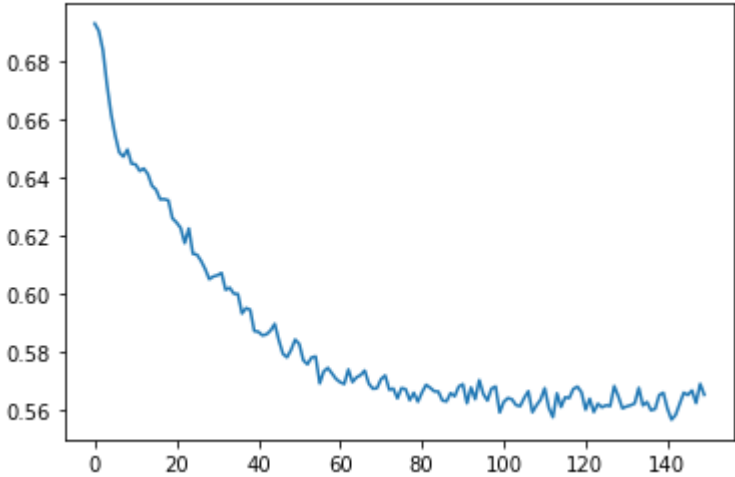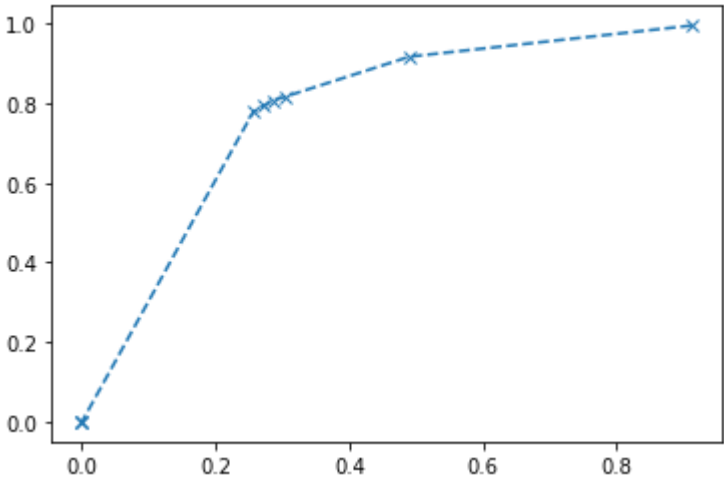
           0       0.93      0.74      0.83      2373
           1       0.45      0.78      0.57       627

    accuracy                           0.75      3000
   macro avg       0.69      0.76      0.70      3000
weighted avg       0.83      0.75      0.77      3000
```

Assumptions

The Recall score is the highest for the the RandomOverSampler model with medium complexity and dropout.

0.39, 0.59 - Base (0.3, 0.2)

0.83 - RandomOverSampler (0.5)

0.78 - SMOTE (0.6)

NN Models - High Complexity v2.0

In this iteration, we will build all three models with a higher complexity, with dropout.

Base Model

```
In [81]:   nodes = [5,6,0.5,7,8,0.5,7,6,0.5,5,4]
           result_10 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 50, 100)
```

```
Model: "sequential_18"
_____
Layer (type)                 Output Shape              Param #
=================================================================
dense_108 (Dense)            (None, 3)                 33

dense_109 (Dense)            (None, 5)                 20

dense_110 (Dense)            (None, 6)                 36

dropout_9 (Dropout)          (None, 6)                 0

dense_111 (Dense)            (None, 7)                 49

dense_112 (Dense)            (None, 8)                 64

dropout_10 (Dropout)         (None, 8)                 0

dense_113 (Dense)            (None, 7)                 63

dense_114 (Dense)            (None, 6)                 48

dropout_11 (Dropout)         (None, 6)                 0

dense_115 (Dense)            (None, 5)                 35

dense_116 (Dense)            (None, 4)                 24

dense_117 (Dense)            (None, 1)                 5
=================================================================
Total params: 377
Trainable params: 377
Non-trainable params: 0
_____


Building NN Model

Epoch 1/50
70/70 [==============================] - 0s 1ms/step - loss: 0.6152
```

```
Epoch 2/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5461
Epoch 3/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5247
Epoch 4/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5190
Epoch 5/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5120
Epoch 6/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5072
Epoch 7/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5042
Epoch 8/50
70/70 [==============================] - 0s 1ms/step - loss: 0.5020
Epoch 9/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4988
Epoch 10/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4962
Epoch 11/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4946
Epoch 12/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4911
Epoch 13/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4873
Epoch 14/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4825
Epoch 15/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4837
Epoch 16/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4830
Epoch 17/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4827
Epoch 18/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4792
Epoch 19/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4787
Epoch 20/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4736
Epoch 21/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4789
Epoch 22/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4748
Epoch 23/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4709
Epoch 24/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4718
Epoch 25/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4698
Epoch 26/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4711
Epoch 27/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4675
Epoch 28/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4703
Epoch 29/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4663
Epoch 30/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4649
Epoch 31/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4685
Epoch 32/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4666
Epoch 33/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4663
Epoch 34/50
```

```
70/70 [==============================] - 0s 1ms/step - loss: 0.4662
Epoch 35/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4665
Epoch 36/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4657
Epoch 37/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4616
Epoch 38/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4642
Epoch 39/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4663
Epoch 40/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4621
Epoch 41/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4627
Epoch 42/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4584
Epoch 43/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4581
Epoch 44/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4601
Epoch 45/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4629
Epoch 46/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4609
Epoch 47/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4585
Epoch 48/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4557
Epoch 49/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4594
Epoch 50/50
70/70 [==============================] - 0s 1ms/step - loss: 0.4517
```

_____
_____

Model Summary

_____
_____

ROC Curve

AUC ROC Score : 0.741381813342689

In [82]:
```python
eval_model(result_10[0], result_10[1], result_10[2], 0.3)
```
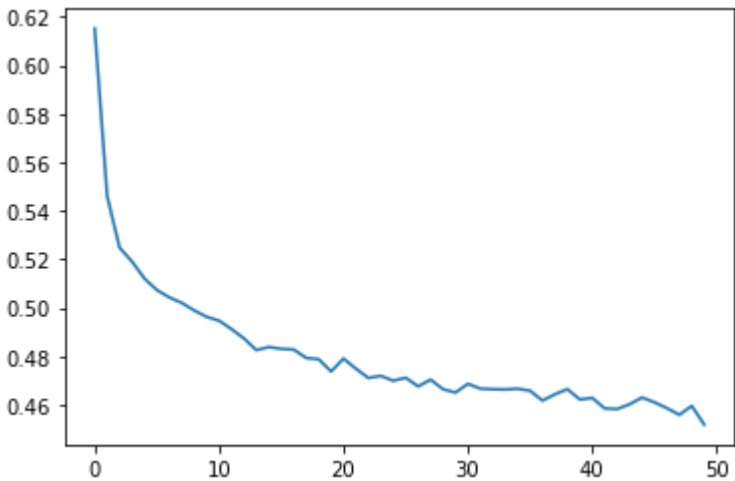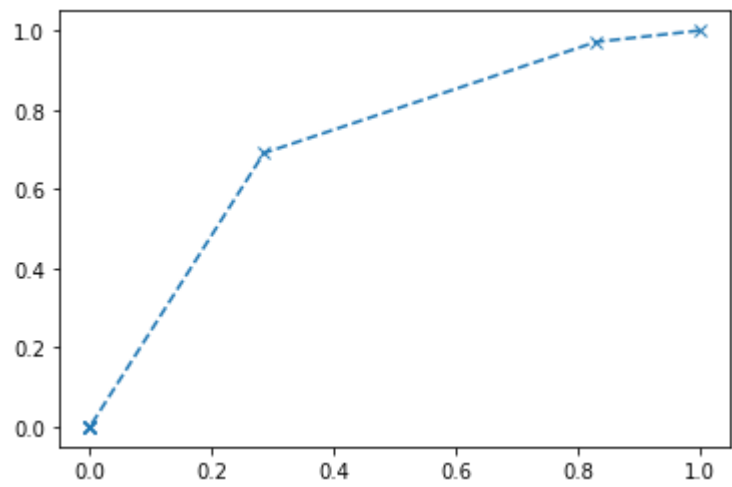
```
              precision    recall  f1-score   support

           0       0.90      0.71      0.80      2373
           1       0.39      0.69      0.50       627

    accuracy                           0.71      3000
   macro avg       0.64      0.70      0.65      3000
weighted avg       0.79      0.71      0.73      3000
```

RandomOverSampler

In [83]:
```python
over_sample = RandomOverSampler(sampling_strategy="minority", random_state=1)
result_11 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 50, 100, over_
```

Model: "sequential_19"

Layer (type)	Output Shape	Param #
dense_118 (Dense)	(None, 3)	33
dense_119 (Dense)	(None, 5)	20
dense_120 (Dense)	(None, 6)	36
dropout_12 (Dropout)	(None, 6)	0
dense_121 (Dense)	(None, 7)	49
dense_122 (Dense)	(None, 8)	64
dropout_13 (Dropout)	(None, 8)	0
dense_123 (Dense)	(None, 7)	63
dense_124 (Dense)	(None, 6)	48
dropout_14 (Dropout)	(None, 6)	0
dense_125 (Dense)	(None, 5)	35

```
dense_126 (Dense)              (None, 4)              24
_____
dense_127 (Dense)              (None, 1)              5
=================================================================
Total params: 377
Trainable params: 377
Non-trainable params: 0
_____


Building NN Model

Epoch 1/50
112/112 [==============================] - 0s 1ms/step - loss: 0.6946
Epoch 2/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6932
Epoch 3/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6932
Epoch 4/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6931
Epoch 5/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6932A: 0s - loss: 0.693
Epoch 6/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6931
Epoch 7/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6930
Epoch 8/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6925
Epoch 9/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6891
Epoch 10/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6765
Epoch 11/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6605
Epoch 12/50
112/112 [==============================] - 0s 1ms/step - loss: 0.6532
Epoch 13/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6400
Epoch 14/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6251
Epoch 15/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6129
Epoch 16/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6055
Epoch 17/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6027
Epoch 18/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5977
Epoch 19/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5976
Epoch 20/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5929
Epoch 21/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5942
Epoch 22/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5885
Epoch 23/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5852
Epoch 24/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5822
Epoch 25/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5847
Epoch 26/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5828
Epoch 27/50
```

```
112/112 [==============================] - 0s 2ms/step - loss: 0.5833
Epoch 28/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5857
Epoch 29/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5746
Epoch 30/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5773
Epoch 31/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5759
Epoch 32/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5678
Epoch 33/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5728
Epoch 34/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5739
Epoch 35/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5747
Epoch 36/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5708
Epoch 37/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5678
Epoch 38/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5683
Epoch 39/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5639
Epoch 40/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5700
Epoch 41/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5624
Epoch 42/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5671
Epoch 43/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5676
Epoch 44/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5615
Epoch 45/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5646
Epoch 46/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5581
Epoch 47/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5620
Epoch 48/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5569
Epoch 49/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5563
Epoch 50/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5633
```

_____
_____

Model Summary
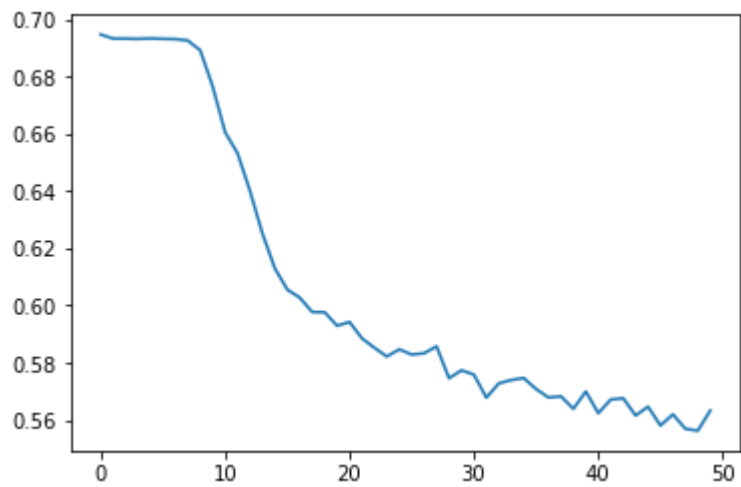
ROC Curve
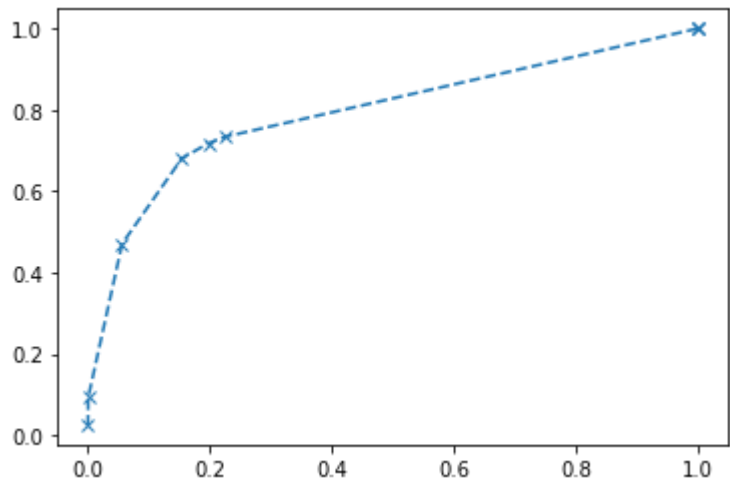
AUC ROC Score :   0.8152212120540021

```
In [84]:  eval_model(result_11[0], result_11[1], result_11[2], 0.4)
```

	precision	recall	f1-score	support
0	0.92	0.77	0.84	2373
1	0.46	0.73	0.57	627
accuracy			0.77	3000
macro avg	0.69	0.75	0.70	3000
weighted avg	0.82	0.77	0.78	3000

SMOTE

```
In [85]:  over_sample = SMOTE(sampling_strategy="minority", random_state=1)
          result_12 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 50, 100, over_
```

Model: "sequential_20"

Layer (type)	Output Shape	Param #
dense_128 (Dense)	(None, 3)	33

```
dense_129 (Dense)              (None, 5)              20
_____
dense_130 (Dense)              (None, 6)              36
_____
dropout_15 (Dropout)           (None, 6)              0
_____
dense_131 (Dense)              (None, 7)              49
_____
dense_132 (Dense)              (None, 8)              64
_____
dropout_16 (Dropout)           (None, 8)              0
_____
dense_133 (Dense)              (None, 7)              63
_____
dense_134 (Dense)              (None, 6)              48
_____
dropout_17 (Dropout)           (None, 6)              0
_____
dense_135 (Dense)              (None, 5)              35
_____
dense_136 (Dense)              (None, 4)              24
_____
dense_137 (Dense)              (None, 1)              5
===============================================================
Total params: 377
Trainable params: 377
Non-trainable params: 0
_____


Building NN Model

Epoch 1/50
112/112 [==============================] - 0s 1ms/step - loss: 0.6924
Epoch 2/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6903
Epoch 3/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6784
Epoch 4/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6571
Epoch 5/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6383
Epoch 6/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6303
Epoch 7/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6147
Epoch 8/50
112/112 [==============================] - 0s 2ms/step - loss: 0.6116
Epoch 9/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5954
Epoch 10/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5932
Epoch 11/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5889
Epoch 12/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5836
Epoch 13/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5783
Epoch 14/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5766
Epoch 15/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5755
Epoch 16/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5713
Epoch 17/50
```

```
112/112 [==============================] - 0s 2ms/step - loss: 0.5706
Epoch 18/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5735
Epoch 19/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5685
Epoch 20/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5696
Epoch 21/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5673
Epoch 22/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5613
Epoch 23/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5660
Epoch 24/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5668
Epoch 25/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5669
Epoch 26/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5664
Epoch 27/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5628
Epoch 28/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5607
Epoch 29/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5641
Epoch 30/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5645
Epoch 31/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5631
Epoch 32/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5657
Epoch 33/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5640
Epoch 34/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5662
Epoch 35/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5625
Epoch 36/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5601
Epoch 37/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5608
Epoch 38/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5566
Epoch 39/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5648
Epoch 40/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5634
Epoch 41/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5571
Epoch 42/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5614
Epoch 43/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5566
Epoch 44/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5582
Epoch 45/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5562A: 0s - loss: 0.5
Epoch 46/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5620
Epoch 47/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5589
Epoch 48/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5567
Epoch 49/50
112/112 [==============================] - 0s 2ms/step - loss: 0.5610
```

```
Epoch 50/50
112/112 [==============================] - 0s 1ms/step - loss: 0.5562
```

_____

_____

Model Summary

_____

_____
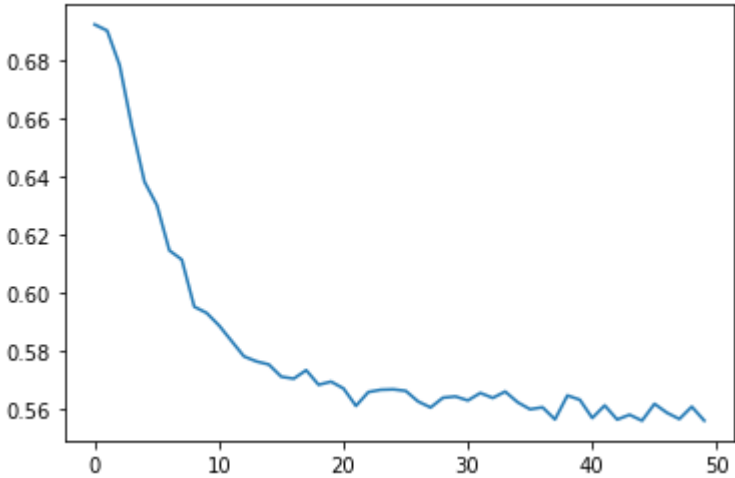
ROC Curve
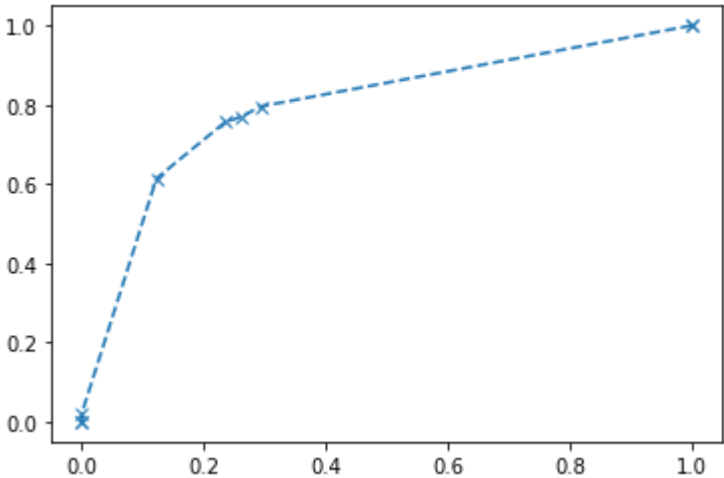
AUC ROC Score :   0.819171823363719

In [86]:   eval_model(result_12[0], result_12[1], result_12[2], 0.4)

```
              precision    recall  f1-score   support

           0       0.92      0.74      0.82      2373
           1       0.44      0.77      0.56       627

    accuracy                           0.74      3000
   macro avg       0.68      0.75      0.69      3000
weighted avg       0.82      0.74      0.77      3000
```

Assumptions

The scores have dropped a bit after increasing the model complexity.

    0.69 - Base (0.3)

0.73 - RandomOverSampler (0.4)

0.77 - SMOTE (0.4)

NN Models - Low Complexity v2.0

We will now create the models with very low complexity, and with dropout.

Base Model

```
In [87]:   nodes = [6,0.5]
           result_20 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 50)
```

```
Model: "sequential_21"
_____
Layer (type)                 Output Shape              Param #
=================================================================
dense_138 (Dense)            (None, 3)                 33

_____
dense_139 (Dense)            (None, 6)                 24

_____
dropout_18 (Dropout)         (None, 6)                 0

_____
dense_140 (Dense)            (None, 1)                 7
=================================================================
Total params: 64
Trainable params: 64
Non-trainable params: 0
_____


Building NN Model

Epoch 1/50
219/219 [==============================] - 0s 1ms/step - loss: 0.6419
Epoch 2/50
219/219 [==============================] - 0s 1ms/step - loss: 0.5519
Epoch 3/50
219/219 [==============================] - 0s 1ms/step - loss: 0.5271
Epoch 4/50
219/219 [==============================] - 0s 1ms/step - loss: 0.5106
Epoch 5/50
219/219 [==============================] - 0s 1ms/step - loss: 0.5037
Epoch 6/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4870
Epoch 7/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4824
Epoch 8/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4730
Epoch 9/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4665
Epoch 10/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4646
Epoch 11/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4695
Epoch 12/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4657
Epoch 13/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4593
```

```
Epoch 14/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4613
Epoch 15/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4626
Epoch 16/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4608
Epoch 17/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4607
Epoch 18/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4585
Epoch 19/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4570
Epoch 20/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4589
Epoch 21/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4550
Epoch 22/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4534
Epoch 23/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4551
Epoch 24/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4539
Epoch 25/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4554
Epoch 26/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4512
Epoch 27/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4458
Epoch 28/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4509
Epoch 29/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4487
Epoch 30/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4488
Epoch 31/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4480
Epoch 32/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4484
Epoch 33/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4500
Epoch 34/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4460
Epoch 35/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4438
Epoch 36/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4442
Epoch 37/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4432
Epoch 38/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4375
Epoch 39/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4332A: 0s - loss: 0.4
Epoch 40/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4381
Epoch 41/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4356
Epoch 42/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4344
Epoch 43/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4310
Epoch 44/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4298
Epoch 45/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4290
Epoch 46/50
```

```
219/219 [==============================] - 0s 1ms/step - loss: 0.4273
Epoch 47/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4266
Epoch 48/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4236
Epoch 49/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4254A: 0s - loss: 0.42
Epoch 50/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4228
```

_____
_____

Model Summary

_____
_____
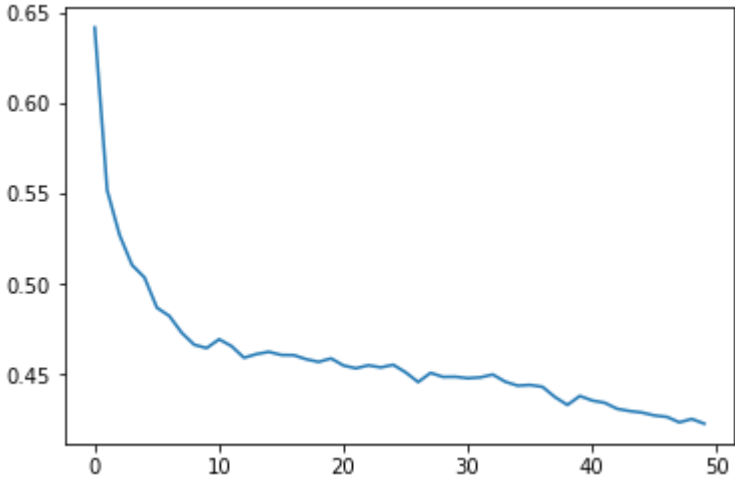
ROC Curve
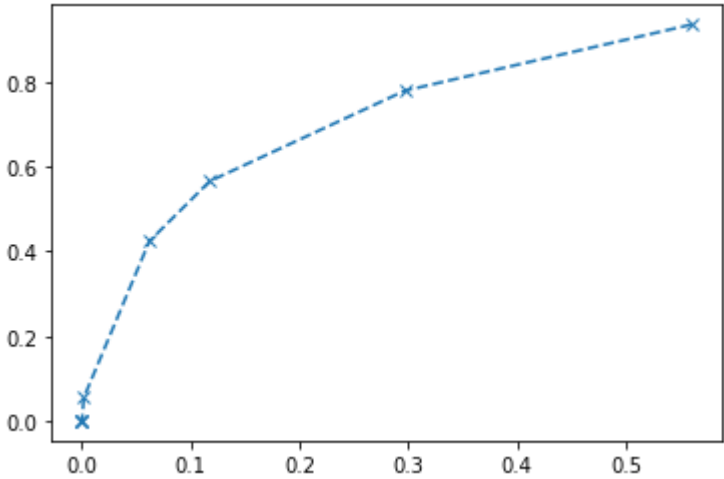
AUC ROC Score : 0.8258340272779026

In [88]:   `eval_model(result_20[0], result_20[1], result_20[2], 0.3)`

```
              precision    recall  f1-score   support

           0       0.89      0.88      0.88      2373
           1       0.56      0.57      0.56       627

    accuracy                           0.82      3000
   macro avg       0.72      0.72      0.72      3000
weighted avg       0.82      0.82      0.82      3000
```

In [89]: `eval_model(result_20[0], result_20[1], result_20[2], 0.2)`

```
              precision    recall  f1-score   support

           0       0.92      0.70      0.80      2373
           1       0.41      0.78      0.54       627

    accuracy                           0.72      3000
   macro avg       0.67      0.74      0.67      3000
weighted avg       0.82      0.72      0.74      3000
```

RandomOverSampler

In [90]:
```
over_sample = RandomOverSampler(sampling_strategy='minority', random_state=1)
result_21 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 150, os=over_s
```

```
Model: "sequential_22"
_____
Layer (type)                 Output Shape              Param #
=================================================================
dense_141 (Dense)            (None, 3)                 33
_____
dense_142 (Dense)            (None, 6)                 24
_____
dropout_19 (Dropout)         (None, 6)                 0
_____
dense_143 (Dense)            (None, 1)                 7
=================================================================
Total params: 64
Trainable params: 64
Non-trainable params: 0
_____


Building NN Model

Epoch 1/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6999
Epoch 2/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6574
Epoch 3/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6425
Epoch 4/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6333
Epoch 5/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6302
Epoch 6/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6269
Epoch 7/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6239
Epoch 8/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6232
Epoch 9/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6192
Epoch 10/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6143
Epoch 11/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6075
Epoch 12/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6118
Epoch 13/150
```

```
            350/350 [==============================] - 0s 1ms/step - loss: 0.6111
            Epoch 14/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.6123
            Epoch 15/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.6064
            Epoch 16/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.6094
            Epoch 17/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.6062
            Epoch 18/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.6047
            Epoch 19/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.6039
            Epoch 20/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.6033
            Epoch 21/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.6028
            Epoch 22/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.6039
            Epoch 23/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5982
            Epoch 24/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5986
            Epoch 25/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5997
            Epoch 26/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5981
            Epoch 27/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5974
            Epoch 28/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5950
            Epoch 29/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5900
            Epoch 30/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5948
            Epoch 31/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5893
            Epoch 32/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5942A: 0s - loss: 0
            Epoch 33/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5883
            Epoch 34/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5871
            Epoch 35/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5841
            Epoch 36/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5818
            Epoch 37/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5769
            Epoch 38/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5746
            Epoch 39/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5721
            Epoch 40/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5692
            Epoch 41/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5692
            Epoch 42/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5660
            Epoch 43/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5676
            Epoch 44/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5678
            Epoch 45/150
            350/350 [==============================] - 0s 1ms/step - loss: 0.5661
```

```
Epoch 46/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5655
Epoch 47/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5621
Epoch 48/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5611
Epoch 49/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5608
Epoch 50/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5606
Epoch 51/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5648
Epoch 52/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5656
Epoch 53/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5590
Epoch 54/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5627
Epoch 55/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5637
Epoch 56/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5663
Epoch 57/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5644
Epoch 58/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5637
Epoch 59/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5637
Epoch 60/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5614
Epoch 61/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5627
Epoch 62/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5627
Epoch 63/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5599
Epoch 64/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5604A: 0s - loss: 0
Epoch 65/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5615
Epoch 66/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5587
Epoch 67/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5613
Epoch 68/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5601
Epoch 69/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5581
Epoch 70/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5592
Epoch 71/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5553
Epoch 72/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5526
Epoch 73/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5570
Epoch 74/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5532
Epoch 75/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5514
Epoch 76/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5460
Epoch 77/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5500
Epoch 78/150
```

```
350/350 [==============================] - 0s 995us/step - loss: 0.5490
Epoch 79/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5486
Epoch 80/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5438
Epoch 81/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5437
Epoch 82/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5475
Epoch 83/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5422
Epoch 84/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5444
Epoch 85/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5456
Epoch 86/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5455
Epoch 87/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5426
Epoch 88/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5405
Epoch 89/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5403
Epoch 90/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5406
Epoch 91/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5393
Epoch 92/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5428
Epoch 93/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5417
Epoch 94/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5382
Epoch 95/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5388
Epoch 96/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5422
Epoch 97/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5417
Epoch 98/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5371
Epoch 99/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5452
Epoch 100/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5393
Epoch 101/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5348
Epoch 102/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5400
Epoch 103/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5400
Epoch 104/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5400
Epoch 105/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5406
Epoch 106/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5339
Epoch 107/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5392
Epoch 108/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5420
Epoch 109/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5406
Epoch 110/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5417
```

```
Epoch 111/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5382
Epoch 112/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5435
Epoch 113/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5381
Epoch 114/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5428
Epoch 115/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5402
Epoch 116/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5385
Epoch 117/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5400
Epoch 118/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5371
Epoch 119/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5414
Epoch 120/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5417
Epoch 121/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5408
Epoch 122/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5421
Epoch 123/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5364
Epoch 124/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5373
Epoch 125/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5398
Epoch 126/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5381
Epoch 127/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5380
Epoch 128/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5405
Epoch 129/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5412
Epoch 130/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5404
Epoch 131/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5411
Epoch 132/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5378
Epoch 133/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5419
Epoch 134/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5381
Epoch 135/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5411
Epoch 136/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5379
Epoch 137/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5408
Epoch 138/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5377
Epoch 139/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5350
Epoch 140/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5404
Epoch 141/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5422
Epoch 142/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5377
Epoch 143/150
```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.5390
Epoch 144/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5372
Epoch 145/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5368
Epoch 146/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5348
Epoch 147/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5387
Epoch 148/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5384
Epoch 149/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5375
Epoch 150/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5411
```

_____

Model Summary

_____
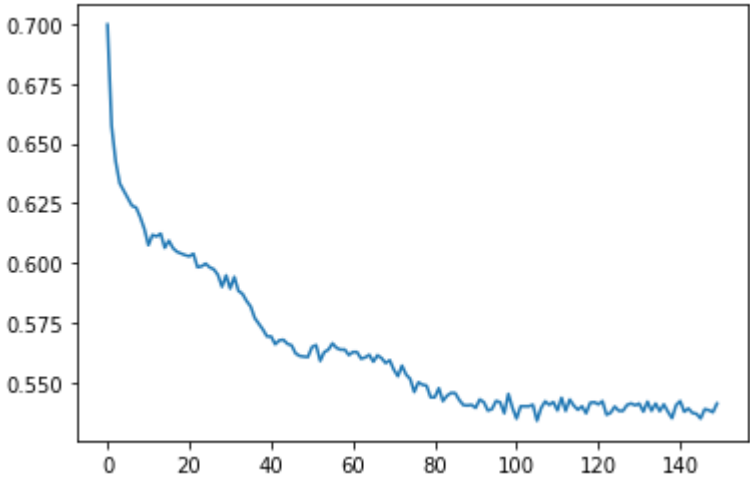
ROC Curve
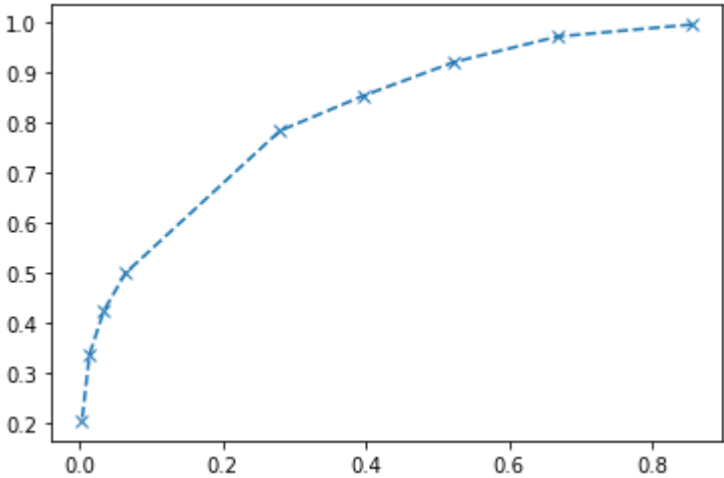
AUC ROC Score : 0.842572037495186

In [91]: `eval_model(result_21[0], result_21[1], result_21[2], 0.5)`

```
              precision      recall   f1-score     support

           0       0.93        0.72       0.81        2373
```

```
                  1        0.43      0.78      0.55       627

         accuracy                              0.73      3000
        macro avg        0.68      0.75      0.68      3000
     weighted avg        0.82      0.73      0.76      3000
```

SMOTE

In [92]:
```python
over_sample = SMOTE(sampling_strategy='minority', random_state=1)
result_22 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 150, os=over_s
```

```
Model: "sequential_23"
_____
Layer (type)                 Output Shape              Param #
=================================================================
dense_144 (Dense)            (None, 3)                 33
_____
dense_145 (Dense)            (None, 6)                 24
_____
dropout_20 (Dropout)         (None, 6)                 0
_____
dense_146 (Dense)            (None, 1)                 7
=================================================================
Total params: 64
Trainable params: 64
Non-trainable params: 0
_____


Building NN Model

Epoch 1/150
350/350 [==============================] - 0s 997us/step - loss: 0.7164
Epoch 2/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6849
Epoch 3/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6675
Epoch 4/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6403
Epoch 5/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6195
Epoch 6/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6018
Epoch 7/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5937
Epoch 8/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5958
Epoch 9/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5850
Epoch 10/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5799
Epoch 11/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5765
Epoch 12/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5714
Epoch 13/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5661
Epoch 14/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5598
Epoch 15/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5575
```

```
Epoch 16/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5518
Epoch 17/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5499
Epoch 18/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5484
Epoch 19/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5482
Epoch 20/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5473
Epoch 21/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5497
Epoch 22/150
350/350 [==============================] - 0s 975us/step - loss: 0.5467
Epoch 23/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5422
Epoch 24/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5429
Epoch 25/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5438
Epoch 26/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5398
Epoch 27/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5437
Epoch 28/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5472
Epoch 29/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5452
Epoch 30/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5420
Epoch 31/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5412
Epoch 32/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5389A: 0s - loss
Epoch 33/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5416
Epoch 34/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5446
Epoch 35/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5384
Epoch 36/150
350/350 [==============================] - 0s 986us/step - loss: 0.5411
Epoch 37/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5413
Epoch 38/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5348
Epoch 39/150
350/350 [==============================] - 0s 992us/step - loss: 0.5372
Epoch 40/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5375
Epoch 41/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5372
Epoch 42/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5431
Epoch 43/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5392
Epoch 44/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5404
Epoch 45/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5380
Epoch 46/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5405
Epoch 47/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5371
Epoch 48/150
```

```
       350/350 [==============================] - 0s 1ms/step - loss: 0.5351
       Epoch 49/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5430
       Epoch 50/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5447
       Epoch 51/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5389
       Epoch 52/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5394
       Epoch 53/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5355
       Epoch 54/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5352
       Epoch 55/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5400
       Epoch 56/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5396
       Epoch 57/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5370
       Epoch 58/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5394
       Epoch 59/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5400
       Epoch 60/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5385
       Epoch 61/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5403
       Epoch 62/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5374
       Epoch 63/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5363
       Epoch 64/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5386
       Epoch 65/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5384
       Epoch 66/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5418
       Epoch 67/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5401
       Epoch 68/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5376
       Epoch 69/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5370
       Epoch 70/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5362
       Epoch 71/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5424
       Epoch 72/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5408
       Epoch 73/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5385
       Epoch 74/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5420
       Epoch 75/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5394
       Epoch 76/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5425
       Epoch 77/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5399
       Epoch 78/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5360
       Epoch 79/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5365
       Epoch 80/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5367
```

```
Epoch 81/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5421
Epoch 82/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5392
Epoch 83/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5351A: 0s - loss: 0
Epoch 84/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5404
Epoch 85/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5431
Epoch 86/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5390
Epoch 87/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5380
Epoch 88/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5433
Epoch 89/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5358
Epoch 90/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5393
Epoch 91/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5406
Epoch 92/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5402
Epoch 93/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5373
Epoch 94/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5424
Epoch 95/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5352
Epoch 96/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5386
Epoch 97/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5371
Epoch 98/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5427
Epoch 99/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5381
Epoch 100/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5372
Epoch 101/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5295
Epoch 102/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5399
Epoch 103/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5405
Epoch 104/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5376
Epoch 105/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5341
Epoch 106/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5335
Epoch 107/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5375
Epoch 108/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5352
Epoch 109/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5366
Epoch 110/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5370
Epoch 111/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5402
Epoch 112/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5366
Epoch 113/150
```

```
       350/350 [==============================] - 0s 1ms/step - loss: 0.5412
       Epoch 114/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5407
       Epoch 115/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5359
       Epoch 116/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5390
       Epoch 117/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5359
       Epoch 118/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5323
       Epoch 119/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5362
       Epoch 120/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5367
       Epoch 121/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5406
       Epoch 122/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5372
       Epoch 123/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5440
       Epoch 124/150
       350/350 [==============================] - 0s 992us/step - loss: 0.5344
       Epoch 125/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5390
       Epoch 126/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5364
       Epoch 127/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5338
       Epoch 128/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5400
       Epoch 129/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5390
       Epoch 130/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5413
       Epoch 131/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5406
       Epoch 132/150
       350/350 [==============================] - 0s 992us/step - loss: 0.5389
       Epoch 133/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5361
       Epoch 134/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5406
       Epoch 135/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5370
       Epoch 136/150
       350/350 [==============================] - 0s 986us/step - loss: 0.5378
       Epoch 137/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5369
       Epoch 138/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5390
       Epoch 139/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5422
       Epoch 140/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5398
       Epoch 141/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5322
       Epoch 142/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5354
       Epoch 143/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5344
       Epoch 144/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5365
       Epoch 145/150
       350/350 [==============================] - 0s 1ms/step - loss: 0.5361
```

```
Epoch 146/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5356
Epoch 147/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5350
Epoch 148/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5357
Epoch 149/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5379
Epoch 150/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5389
```

_____

Model Summary

_____
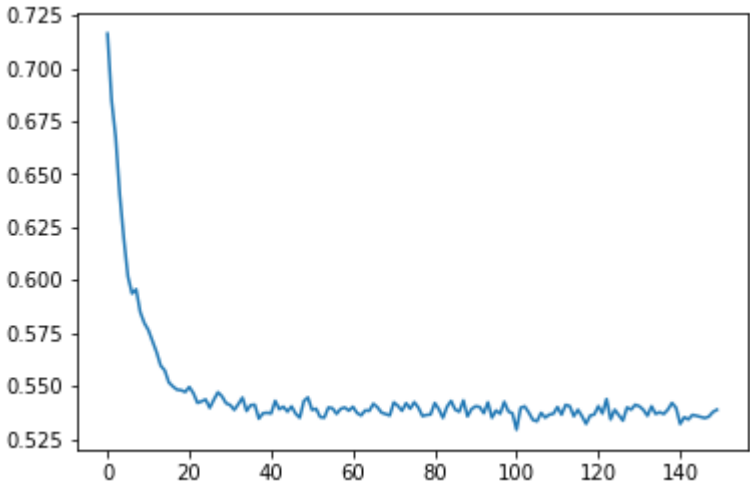
ROC Curve
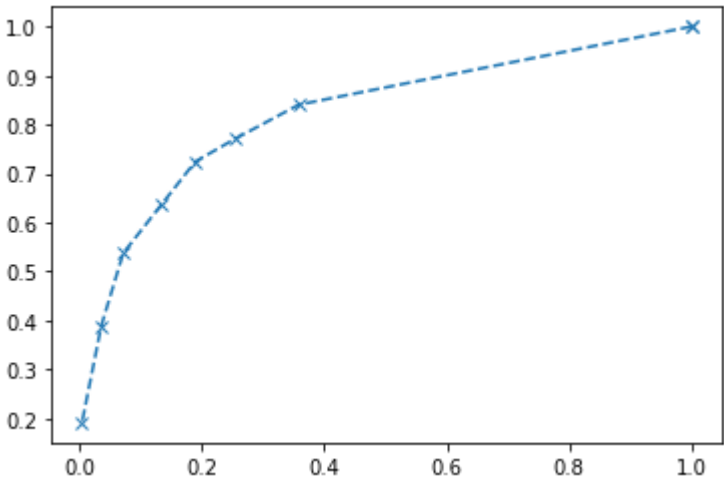
AUC ROC Score : 0.8305390722717225

In [93]: `eval_model(result_22[0], result_22[1], result_22[2], 0.3)`

	precision	recall	f1-score	support
0	0.94	0.64	0.76	2373
1	0.38	0.84	0.53	627
accuracy			0.68	3000
macro avg	0.66	0.74	0.64	3000

```
weighted avg        0.82        0.68        0.71        3000
```

Assumptions

Lowering the compexity has improve the scores.

> **0.57, 0.78 - Base (0.3, 0.2)**
>
> **0.78 - RandomOverSampler (0.5)**
>
> **0.84 - SMOTE (0.3)**

NN Models - Low Complexity v2.1

The models in this iteration will have two hidden layers.

Base Model

In [94]:
```python
nodes = [6,0.5,4,0.5]
result_30 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 50)
```

```
Model: "sequential_24"
_____
Layer (type)                 Output Shape              Param #
=================================================================
dense_147 (Dense)            (None, 3)                 33
_____
dense_148 (Dense)            (None, 6)                 24
_____
dropout_21 (Dropout)         (None, 6)                 0
_____
dense_149 (Dense)            (None, 4)                 28
_____
dropout_22 (Dropout)         (None, 4)                 0
_____
dense_150 (Dense)            (None, 1)                 5
=================================================================
Total params: 90
Trainable params: 90
Non-trainable params: 0
_____


Building NN Model

Epoch 1/50
219/219 [==============================] - 0s 1ms/step - loss: 0.6306
Epoch 2/50
219/219 [==============================] - 0s 1ms/step - loss: 0.5597
Epoch 3/50
219/219 [==============================] - 0s 1ms/step - loss: 0.5361
Epoch 4/50
219/219 [==============================] - 0s 1ms/step - loss: 0.5212
Epoch 5/50
219/219 [==============================] - 0s 1ms/step - loss: 0.5123
Epoch 6/50
```

```
219/219 [==============================] - 0s 1ms/step - loss: 0.5011
Epoch 7/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4937
Epoch 8/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4882
Epoch 9/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4870
Epoch 10/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4838
Epoch 11/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4822
Epoch 12/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4733
Epoch 13/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4708
Epoch 14/50
219/219 [==============================] - 0s 2ms/step - loss: 0.4693
Epoch 15/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4673
Epoch 16/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4695
Epoch 17/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4636
Epoch 18/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4624
Epoch 19/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4593
Epoch 20/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4612
Epoch 21/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4557
Epoch 22/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4532
Epoch 23/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4567
Epoch 24/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4576
Epoch 25/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4500
Epoch 26/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4516
Epoch 27/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4471
Epoch 28/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4480
Epoch 29/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4458
Epoch 30/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4481
Epoch 31/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4451
Epoch 32/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4470
Epoch 33/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4347
Epoch 34/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4424
Epoch 35/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4433
Epoch 36/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4400
Epoch 37/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4339
Epoch 38/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4353
```

```
Epoch 39/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4430
Epoch 40/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4390
Epoch 41/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4431
Epoch 42/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4394
Epoch 43/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4361
Epoch 44/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4351
Epoch 45/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4351
Epoch 46/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4364
Epoch 47/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4411
Epoch 48/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4406
Epoch 49/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4320
Epoch 50/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4334
```

Model Summary
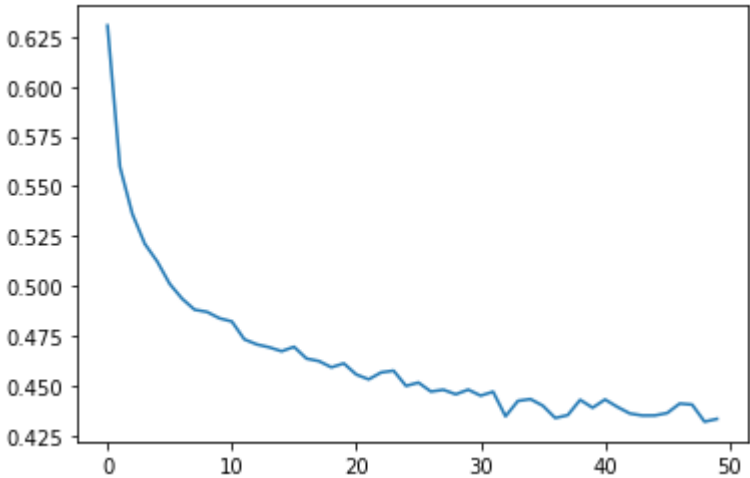
ROC Curve
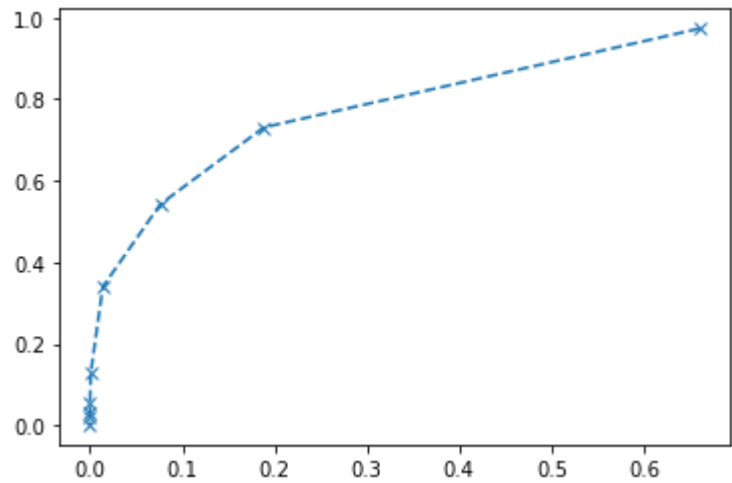
```
AUC ROC Score :   0.8497725945327249
```

In [95]: `eval_model(result_30[0], result_30[1], result_30[2], 0.3)`

```
              precision    recall  f1-score   support

           0       0.88      0.92      0.90      2373
           1       0.65      0.54      0.59       627

    accuracy                           0.84      3000
   macro avg       0.77      0.73      0.75      3000
weighted avg       0.84      0.84      0.84      3000
```

In [96]: `eval_model(result_30[0], result_30[1], result_30[2], 0.2)`

```
              precision    recall  f1-score   support

           0       0.92      0.81      0.86      2373
           1       0.51      0.73      0.60       627

    accuracy                           0.79      3000
   macro avg       0.71      0.77      0.73      3000
weighted avg       0.83      0.79      0.81      3000
```

RandomOverSampler

In [98]:
```
over_sample = RandomOverSampler(sampling_strategy='minority', random_state=1)
result_31 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 150, os=over_s
```

```
Model: "sequential_26"

_____
Layer (type)                 Output Shape              Param #
=================================================================
dense_155 (Dense)            (None, 3)                 33
_____
dense_156 (Dense)            (None, 6)                 24
_____
dropout_25 (Dropout)         (None, 6)                 0
_____
dense_157 (Dense)            (None, 4)                 28
_____
dropout_26 (Dropout)         (None, 4)                 0
_____
```

```
dense_158 (Dense)              (None, 1)                 5
=================================================================
Total params: 90
Trainable params: 90
Non-trainable params: 0
```

_____

Building NN Model

```
Epoch 1/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6892
Epoch 2/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6837
Epoch 3/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6734
Epoch 4/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6642
Epoch 5/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6601
Epoch 6/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6562
Epoch 7/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6549
Epoch 8/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6526
Epoch 9/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6485
Epoch 10/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6485
Epoch 11/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6491
Epoch 12/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6447
Epoch 13/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6451
Epoch 14/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6477
Epoch 15/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6451
Epoch 16/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6432
Epoch 17/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6456
Epoch 18/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6454
Epoch 19/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6396
Epoch 20/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6457
Epoch 21/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6438
Epoch 22/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6410
Epoch 23/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6406
Epoch 24/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6418
Epoch 25/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6404
Epoch 26/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6395
Epoch 27/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6392
Epoch 28/150
```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.6398
Epoch 29/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6442
Epoch 30/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6403
Epoch 31/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6438
Epoch 32/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6381
Epoch 33/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6466
Epoch 34/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6445
Epoch 35/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6388
Epoch 36/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6379
Epoch 37/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6395
Epoch 38/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6406
Epoch 39/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6403
Epoch 40/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6431
Epoch 41/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6387
Epoch 42/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6422
Epoch 43/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6388
Epoch 44/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6402
Epoch 45/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6361
Epoch 46/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6360
Epoch 47/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6376
Epoch 48/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6313
Epoch 49/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6316
Epoch 50/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6339
Epoch 51/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6306
Epoch 52/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6260
Epoch 53/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6282
Epoch 54/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6192
Epoch 55/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6287
Epoch 56/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6292
Epoch 57/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6289
Epoch 58/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6234
Epoch 59/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6288
Epoch 60/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6218
```

```
Epoch 61/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6257
Epoch 62/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6262
Epoch 63/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6253
Epoch 64/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6192
Epoch 65/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6221
Epoch 66/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6239
Epoch 67/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6191
Epoch 68/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6270
Epoch 69/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6212
Epoch 70/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6257
Epoch 71/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6253
Epoch 72/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6245
Epoch 73/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6229
Epoch 74/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6248
Epoch 75/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6190
Epoch 76/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6277
Epoch 77/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6209
Epoch 78/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6204
Epoch 79/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6209
Epoch 80/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6158
Epoch 81/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6247
Epoch 82/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6276
Epoch 83/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6199
Epoch 84/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6276
Epoch 85/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6228
Epoch 86/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6226
Epoch 87/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6240
Epoch 88/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6199
Epoch 89/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6205
Epoch 90/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6258
Epoch 91/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6243
Epoch 92/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6206
Epoch 93/150
```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.6221
Epoch 94/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6246
Epoch 95/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6238
Epoch 96/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6166
Epoch 97/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6166
Epoch 98/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6179
Epoch 99/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6123
Epoch 100/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6167
Epoch 101/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6173
Epoch 102/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6136
Epoch 103/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6182
Epoch 104/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6100
Epoch 105/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6152
Epoch 106/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6136
Epoch 107/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6138
Epoch 108/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6126
Epoch 109/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6169
Epoch 110/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6156
Epoch 111/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6119
Epoch 112/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6154
Epoch 113/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6095
Epoch 114/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6147
Epoch 115/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6091
Epoch 116/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6111
Epoch 117/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6096
Epoch 118/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6132
Epoch 119/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6106
Epoch 120/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6156
Epoch 121/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6137
Epoch 122/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6110
Epoch 123/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6132
Epoch 124/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6133
Epoch 125/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6097
```

```
Epoch 126/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6120
Epoch 127/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6169
Epoch 128/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6128
Epoch 129/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6144
Epoch 130/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6102
Epoch 131/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6157
Epoch 132/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6152
Epoch 133/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6115
Epoch 134/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6111
Epoch 135/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6166
Epoch 136/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6112
Epoch 137/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6104
Epoch 138/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6120
Epoch 139/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6123
Epoch 140/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6130
Epoch 141/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6110
Epoch 142/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6148
Epoch 143/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6134
Epoch 144/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6114
Epoch 145/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6158
Epoch 146/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6106
Epoch 147/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6140
Epoch 148/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6181
Epoch 149/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6184
Epoch 150/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6104
```

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Model Summary
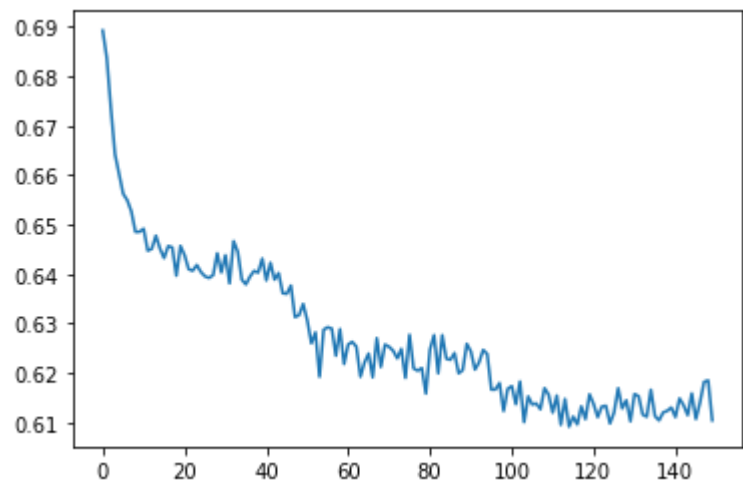
ROC Curve
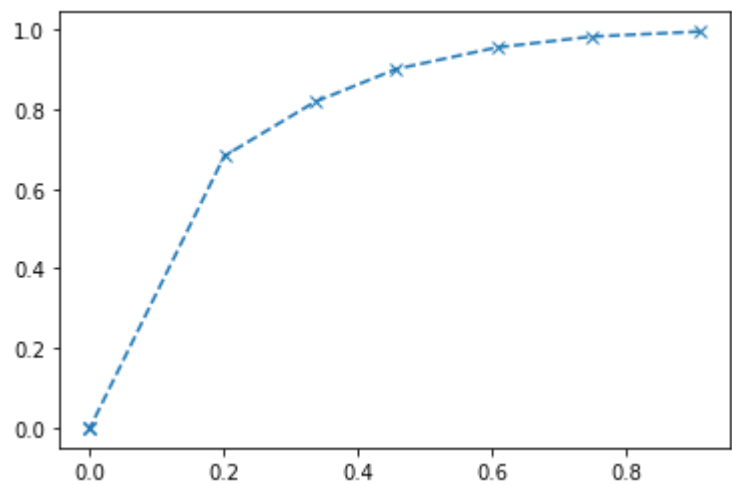
AUC ROC Score :   0.8070948355065728

```
In [99]:  eval_model(result_31[0], result_31[1], result_31[2], 0.6)
```

	precision	recall	f1-score	support
0	0.91	0.80	0.85	2373
1	0.47	0.68	0.56	627
accuracy			0.78	3000
macro avg	0.69	0.74	0.70	3000
weighted avg	0.81	0.78	0.79	3000

SMOTE

```
In [100…  over_sample = SMOTE(sampling_strategy='minority', random_state=1)
          result_32 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 150, os=over_s
```

Model: "sequential_27"

Layer (type)	Output Shape	Param #
dense_159 (Dense)	(None, 3)	33

dense_160 (Dense)	(None, 6)	24
dropout_27 (Dropout)	(None, 6)	0
dense_161 (Dense)	(None, 4)	28
dropout_28 (Dropout)	(None, 4)	0
dense_162 (Dense)	(None, 1)	5

```
=================================================================
Total params: 90
Trainable params: 90
Non-trainable params: 0
```

_____

Building NN Model

```
Epoch 1/150
350/350 [==============================] - 0s 1ms/step - loss: 0.7283
Epoch 2/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6920
Epoch 3/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6875
Epoch 4/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6829
Epoch 5/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6811
Epoch 6/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6789
Epoch 7/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6740
Epoch 8/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6708
Epoch 9/150
350/350 [==============================] - ETA: 0s - loss: 0.661 - 0s 1ms/step - loss:
0.6604
Epoch 10/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6530
Epoch 11/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6338
Epoch 12/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6273
Epoch 13/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6203
Epoch 14/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6146
Epoch 15/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6122
Epoch 16/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6127
Epoch 17/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6119
Epoch 18/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6150
Epoch 19/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6140
Epoch 20/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6113
Epoch 21/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6080
Epoch 22/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6041
Epoch 23/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6050
```

```
Epoch 24/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6080
Epoch 25/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6071
Epoch 26/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6053
Epoch 27/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6045
Epoch 28/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6084
Epoch 29/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6042
Epoch 30/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6053
Epoch 31/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6057
Epoch 32/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6041
Epoch 33/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6050
Epoch 34/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6049
Epoch 35/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6032
Epoch 36/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6003
Epoch 37/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6002
Epoch 38/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6048
Epoch 39/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5995
Epoch 40/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6006
Epoch 41/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5976
Epoch 42/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5980
Epoch 43/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6036
Epoch 44/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6062
Epoch 45/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5982
Epoch 46/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6012
Epoch 47/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6048
Epoch 48/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6021
Epoch 49/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5968
Epoch 50/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6028
Epoch 51/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6016
Epoch 52/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5986
Epoch 53/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6014
Epoch 54/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5956A: 0s - loss:
Epoch 55/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6013
Epoch 56/150
```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.5978
Epoch 57/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6013
Epoch 58/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6023
Epoch 59/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6033
Epoch 60/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5965
Epoch 61/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5971
Epoch 62/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5967
Epoch 63/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5973
Epoch 64/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5987
Epoch 65/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5956
Epoch 66/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5923
Epoch 67/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5953
Epoch 68/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5908
Epoch 69/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5927
Epoch 70/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5952
Epoch 71/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5934
Epoch 72/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5911
Epoch 73/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5914
Epoch 74/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5878
Epoch 75/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5901
Epoch 76/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5890
Epoch 77/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5909
Epoch 78/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5893
Epoch 79/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5906
Epoch 80/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5907
Epoch 81/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5869
Epoch 82/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5932
Epoch 83/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5937
Epoch 84/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5930
Epoch 85/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5889
Epoch 86/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5947
Epoch 87/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5903
Epoch 88/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5912
```

```
Epoch 89/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5955
Epoch 90/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5898
Epoch 91/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5908
Epoch 92/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5915
Epoch 93/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5892
Epoch 94/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5926
Epoch 95/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5953
Epoch 96/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5928
Epoch 97/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5919
Epoch 98/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5890
Epoch 99/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5850
Epoch 100/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5923
Epoch 101/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5922
Epoch 102/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5945
Epoch 103/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5908
Epoch 104/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5931
Epoch 105/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5937
Epoch 106/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5893
Epoch 107/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5936
Epoch 108/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5893
Epoch 109/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5936
Epoch 110/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5901
Epoch 111/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5878
Epoch 112/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5936
Epoch 113/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5988
Epoch 114/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5962
Epoch 115/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5941
Epoch 116/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5872
Epoch 117/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5915
Epoch 118/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5920
Epoch 119/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5913
Epoch 120/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5903
Epoch 121/150
```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.5967
Epoch 122/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5900A: 0s - loss:
Epoch 123/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5938
Epoch 124/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5932
Epoch 125/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5899
Epoch 126/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5904
Epoch 127/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5914
Epoch 128/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5910
Epoch 129/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5929
Epoch 130/150
350/350 [==============================] - 1s 2ms/step - loss: 0.5926
Epoch 131/150
350/350 [==============================] - 1s 2ms/step - loss: 0.5911
Epoch 132/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5945
Epoch 133/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5921
Epoch 134/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5927
Epoch 135/150
350/350 [==============================] - 1s 1ms/step - loss: 0.5869
Epoch 136/150
350/350 [==============================] - 1s 2ms/step - loss: 0.5872
Epoch 137/150
350/350 [==============================] - 1s 2ms/step - loss: 0.5888
Epoch 138/150
350/350 [==============================] - 1s 2ms/step - loss: 0.5918
Epoch 139/150
350/350 [==============================] - 1s 2ms/step - loss: 0.5931
Epoch 140/150
350/350 [==============================] - 1s 2ms/step - loss: 0.5905
Epoch 141/150
350/350 [==============================] - 1s 1ms/step - loss: 0.5899
Epoch 142/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5897
Epoch 143/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5899
Epoch 144/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5905
Epoch 145/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5908
Epoch 146/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5914
Epoch 147/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5884
Epoch 148/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5924
Epoch 149/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5949
Epoch 150/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5923
```

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Model Summary
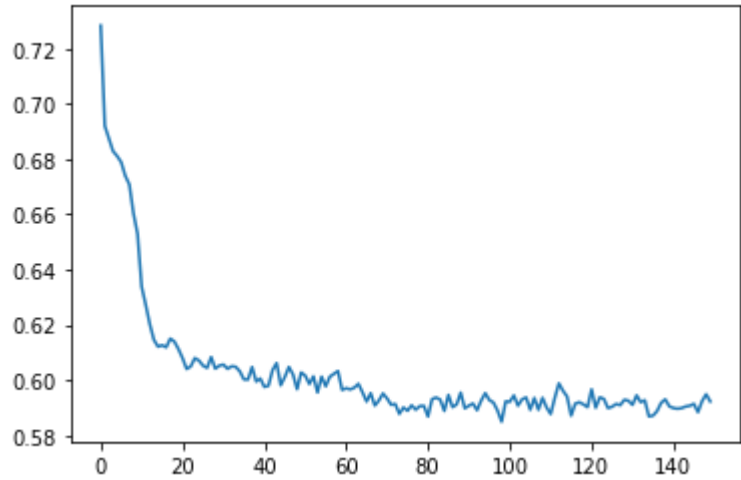
ROC Curve
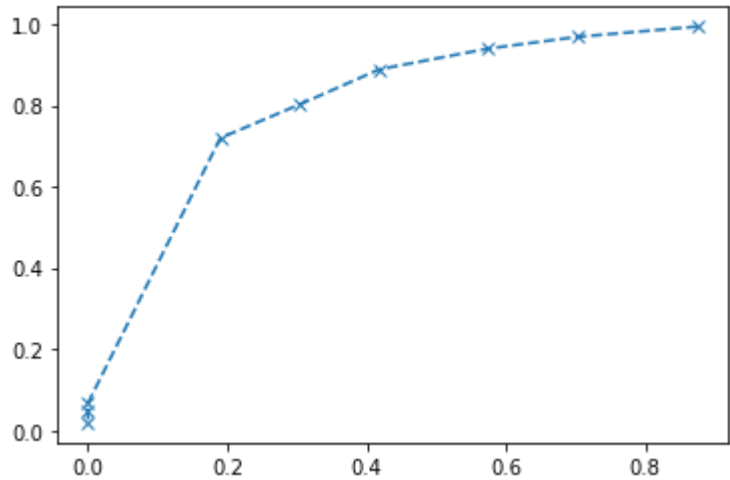
AUC ROC Score : 0.8244468102409417

```
In [101...  eval_model(result_32[0], result_32[1], result_32[2], 0.6)
```

	precision	recall	f1-score	support
0	0.92	0.81	0.86	2373
1	0.50	0.72	0.59	627
accuracy			0.79	3000
macro avg	0.71	0.76	0.72	3000
weighted avg	0.83	0.79	0.80	3000

Assumptions

The scores have dropped in this iteration.

   0.54, 0.73 - Base (0.3, 0.2)

   0.68 - RandomOverSampler (0.6)

   0.72 - SMOTE (0.6)

NN Models - Low Complexity v2.2

The models in this iteration will have three hidden layers, with dropout

Base Model

```
In [103... nodes = [3,8,0.5,3]
         result_40 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 50)
```

Model: "sequential_29"

```
_____
Layer (type)                 Output Shape              Param #
=================================================================
dense_168 (Dense)            (None, 3)                 33
_____
dense_169 (Dense)            (None, 3)                 12
_____
dense_170 (Dense)            (None, 8)                 32
_____
dropout_30 (Dropout)         (None, 8)                 0
_____
dense_171 (Dense)            (None, 3)                 27
_____
dense_172 (Dense)            (None, 1)                 4
=================================================================
Total params: 108
Trainable params: 108
Non-trainable params: 0
_____


Building NN Model

Epoch 1/50
219/219 [==============================] - 0s 1ms/step - loss: 0.6859
Epoch 2/50
219/219 [==============================] - 0s 1ms/step - loss: 0.5461
Epoch 3/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4987
Epoch 4/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4843
Epoch 5/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4771
Epoch 6/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4665
Epoch 7/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4588
Epoch 8/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4533
Epoch 9/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4511
Epoch 10/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4470
Epoch 11/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4459
Epoch 12/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4449
Epoch 13/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4435
Epoch 14/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4384
Epoch 15/50
```

```
219/219 [==============================] - 0s 1ms/step - loss: 0.4424
Epoch 16/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4414
Epoch 17/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4377
Epoch 18/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4350
Epoch 19/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4375
Epoch 20/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4364
Epoch 21/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4335
Epoch 22/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4365
Epoch 23/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4286
Epoch 24/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4301
Epoch 25/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4292
Epoch 26/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4315
Epoch 27/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4277
Epoch 28/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4258
Epoch 29/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4282
Epoch 30/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4268
Epoch 31/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4210
Epoch 32/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4162
Epoch 33/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4163
Epoch 34/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4120
Epoch 35/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4131
Epoch 36/50
219/219 [==============================] - ETA: 0s - loss: 0.408 - 0s 1ms/step - loss:
0.4153
Epoch 37/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4129
Epoch 38/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4070
Epoch 39/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4051
Epoch 40/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4047
Epoch 41/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4066
Epoch 42/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4076
Epoch 43/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4042
Epoch 44/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4053
Epoch 45/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4029
Epoch 46/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4030
Epoch 47/50
```

```
219/219 [==============================] - 0s 1ms/step - loss: 0.4010
Epoch 48/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4007
Epoch 49/50
219/219 [==============================] - 0s 1ms/step - loss: 0.4006
Epoch 50/50
219/219 [==============================] - 0s 1ms/step - loss: 0.3981
```

_____

_____

Model Summary

_____

_____
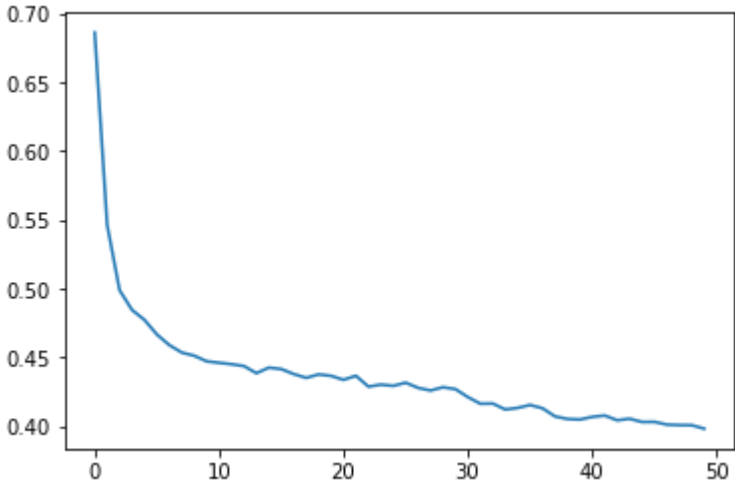
ROC Curve
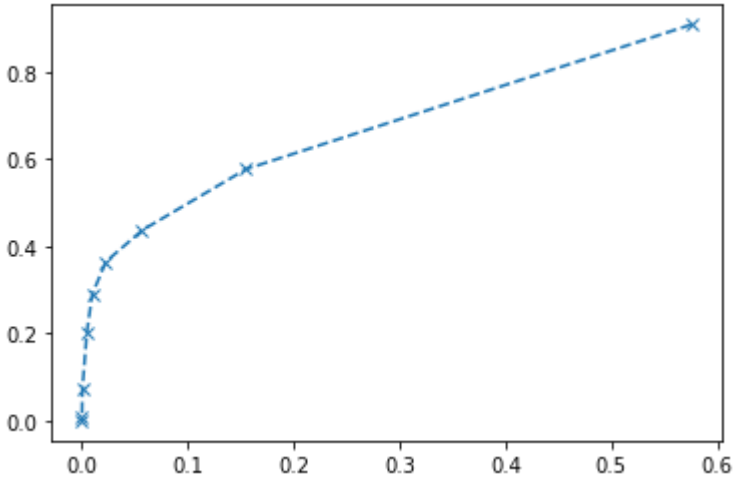
AUC ROC Score :   0.8094334119019727

In [104...   `eval_model(result_40[0], result_40[1], result_40[2], 0.2)`

```
              precision    recall  f1-score   support

           0       0.88      0.84      0.86      2373
           1       0.50      0.58      0.53       627

    accuracy                           0.79      3000
   macro avg       0.69      0.71      0.70      3000
weighted avg       0.80      0.79      0.79      3000
```

RandomOverSampler

In [105...

```
over_sample = RandomOverSampler(sampling_strategy='minority', random_state=1)
result_41 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 150, os=over_s
```

Model: "sequential_30"

Layer (type)	Output Shape	Param #
dense_173 (Dense)	(None, 3)	33
dense_174 (Dense)	(None, 3)	12
dense_175 (Dense)	(None, 8)	32
dropout_31 (Dropout)	(None, 8)	0
dense_176 (Dense)	(None, 3)	27
dense_177 (Dense)	(None, 1)	4

Total params: 108
Trainable params: 108
Non-trainable params: 0

Building NN Model

Epoch 1/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6953
Epoch 2/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6912
Epoch 3/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6818
Epoch 4/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6659
Epoch 5/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6543
Epoch 6/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6448
Epoch 7/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6409
Epoch 8/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6357
Epoch 9/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6243
Epoch 10/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6178
Epoch 11/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6054
Epoch 12/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6048
Epoch 13/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6001
Epoch 14/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5969
Epoch 15/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5937
Epoch 16/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5973
Epoch 17/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5894
Epoch 18/150

```
      350/350 [==============================] - 0s 1ms/step - loss: 0.5868
      Epoch 19/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5909
      Epoch 20/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5887
      Epoch 21/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5865
      Epoch 22/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5859
      Epoch 23/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5844
      Epoch 24/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5819
      Epoch 25/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5844
      Epoch 26/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5804
      Epoch 27/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5819
      Epoch 28/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5770
      Epoch 29/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5758
      Epoch 30/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5776
      Epoch 31/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5751
      Epoch 32/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5744
      Epoch 33/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5759
      Epoch 34/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5750
      Epoch 35/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5774
      Epoch 36/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5780
      Epoch 37/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5768
      Epoch 38/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5733
      Epoch 39/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5776
      Epoch 40/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5747
      Epoch 41/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5723
      Epoch 42/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5765
      Epoch 43/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5723
      Epoch 44/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5769
      Epoch 45/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5731
      Epoch 46/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5732
      Epoch 47/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5827
      Epoch 48/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5801
      Epoch 49/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5792
      Epoch 50/150
      350/350 [==============================] - 0s 1ms/step - loss: 0.5757
```

```
Epoch 51/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5717
Epoch 52/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5762
Epoch 53/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5745
Epoch 54/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5704
Epoch 55/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5745
Epoch 56/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5767
Epoch 57/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5738
Epoch 58/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5777
Epoch 59/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5765
Epoch 60/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5781
Epoch 61/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5706
Epoch 62/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5731
Epoch 63/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5746
Epoch 64/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5721
Epoch 65/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5739
Epoch 66/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5742
Epoch 67/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5760
Epoch 68/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5735
Epoch 69/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5720A: 0s - loss: 0
Epoch 70/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5756
Epoch 71/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5760
Epoch 72/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5752
Epoch 73/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5684
Epoch 74/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5733
Epoch 75/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5718
Epoch 76/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5782
Epoch 77/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5761
Epoch 78/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5756
Epoch 79/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5726
Epoch 80/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5734
Epoch 81/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5736
Epoch 82/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5745
Epoch 83/150
```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.5690
Epoch 84/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5740
Epoch 85/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5722
Epoch 86/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5715
Epoch 87/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5770
Epoch 88/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5818
Epoch 89/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5780
Epoch 90/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5726
Epoch 91/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5746
Epoch 92/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5714
Epoch 93/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5780
Epoch 94/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5719
Epoch 95/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5765
Epoch 96/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5729
Epoch 97/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5757
Epoch 98/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5719
Epoch 99/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5719
Epoch 100/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5719
Epoch 101/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5774
Epoch 102/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5783
Epoch 103/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5780
Epoch 104/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5761
Epoch 105/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5773
Epoch 106/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5713
Epoch 107/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5738
Epoch 108/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5775
Epoch 109/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5742
Epoch 110/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5682
Epoch 111/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5744
Epoch 112/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5697
Epoch 113/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5756
Epoch 114/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5754
Epoch 115/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5781
```

```
Epoch 116/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5776
Epoch 117/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5756
Epoch 118/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5762
Epoch 119/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5729
Epoch 120/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5748
Epoch 121/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5720
Epoch 122/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5771
Epoch 123/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5690
Epoch 124/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5733
Epoch 125/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5740
Epoch 126/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5763
Epoch 127/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5743
Epoch 128/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5720
Epoch 129/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5739
Epoch 130/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5720
Epoch 131/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5743
Epoch 132/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5732
Epoch 133/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5737
Epoch 134/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5745
Epoch 135/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5738
Epoch 136/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5717
Epoch 137/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5731
Epoch 138/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5680
Epoch 139/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5712
Epoch 140/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5715
Epoch 141/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5762
Epoch 142/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5668
Epoch 143/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5727
Epoch 144/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5720
Epoch 145/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5755
Epoch 146/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5726
Epoch 147/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5804
Epoch 148/150
```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.5694
Epoch 149/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5758
Epoch 150/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5682
```

_____
_____

Model Summary

_____
_____
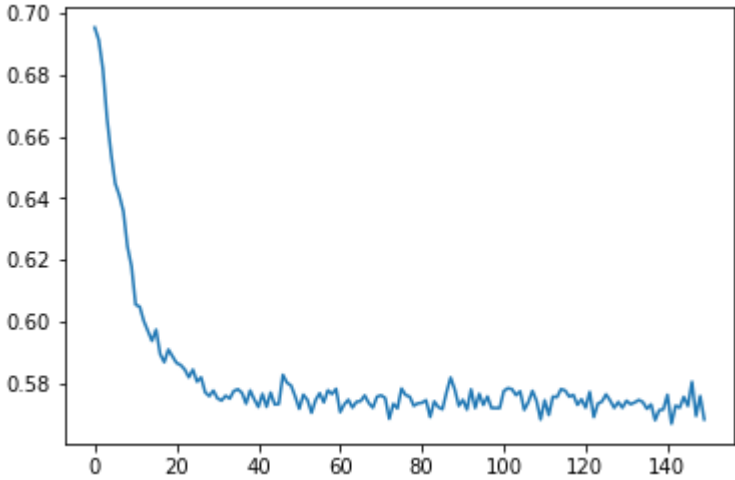
ROC Curve
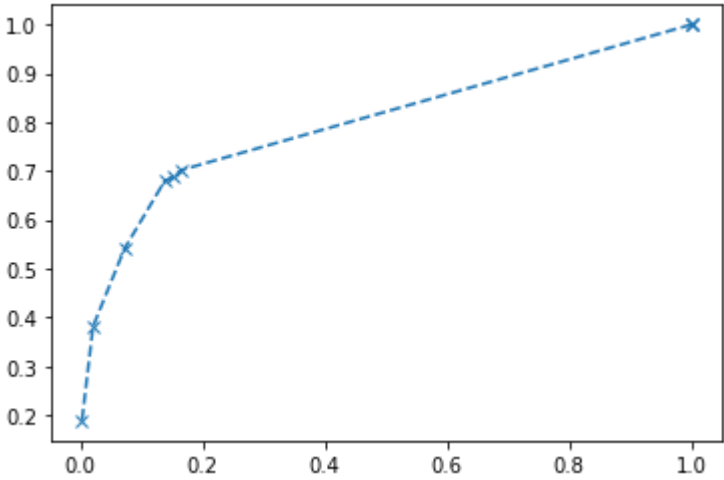
AUC ROC Score :   0.8017408767292324

```
In [106...   eval_model(result_41[0], result_41[1], result_41[2], 0.4)
```

	precision	recall	f1-score	support
0	0.91	0.83	0.87	2373
1	0.53	0.70	0.60	627
accuracy			0.81	3000
macro avg	0.72	0.77	0.74	3000
weighted avg	0.83	0.81	0.82	3000

SMOTE

```
In [107…    over_sample = SMOTE(sampling_strategy='minority', random_state=1)
            result_42 = nn_model(X, y, nodes, "relu", "adam", "binary_crossentropy", 150, os=over_s
```

Model: "sequential_31"

_____

Layer (type)	Output Shape	Param #
dense_178 (Dense)	(None, 3)	33
dense_179 (Dense)	(None, 3)	12
dense_180 (Dense)	(None, 8)	32
dropout_32 (Dropout)	(None, 8)	0
dense_181 (Dense)	(None, 3)	27
dense_182 (Dense)	(None, 1)	4

==
Total params: 108
Trainable params: 108
Non-trainable params: 0

_____

Building NN Model

Epoch 1/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6551
Epoch 2/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6199
Epoch 3/150
350/350 [==============================] - 0s 1ms/step - loss: 0.6048
Epoch 4/150
350/350 [==============================] - 0s 986us/step - loss: 0.5906
Epoch 5/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5745
Epoch 6/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5647
Epoch 7/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5550
Epoch 8/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5409
Epoch 9/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5409
Epoch 10/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5363
Epoch 11/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5287
Epoch 12/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5233
Epoch 13/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5248
Epoch 14/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5215
Epoch 15/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5243
Epoch 16/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5244
Epoch 17/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5212
Epoch 18/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5242
Epoch 19/150

```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.5184A: 0s - loss:
Epoch 20/150
350/350 [==============================] - ETA: 0s - loss: 0.523 - 0s 1ms/step - loss:
0.5220
Epoch 21/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5203
Epoch 22/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5188
Epoch 23/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5217
Epoch 24/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5190
Epoch 25/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5215
Epoch 26/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5181
Epoch 27/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5216
Epoch 28/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5220
Epoch 29/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5167
Epoch 30/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5188
Epoch 31/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5201
Epoch 32/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5188
Epoch 33/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5218
Epoch 34/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5156
Epoch 35/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5171
Epoch 36/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5126
Epoch 37/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5172
Epoch 38/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5125
Epoch 39/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5189
Epoch 40/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5186
Epoch 41/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5158
Epoch 42/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5198
Epoch 43/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5158
Epoch 44/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5158
Epoch 45/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5156
Epoch 46/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5174
Epoch 47/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5177
Epoch 48/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5193
Epoch 49/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5186
Epoch 50/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5142
Epoch 51/150
```

```
         350/350 [==============================] - 0s 1ms/step - loss: 0.5173
         Epoch 52/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5161
         Epoch 53/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5157
         Epoch 54/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5174
         Epoch 55/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5147
         Epoch 56/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5184
         Epoch 57/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5143
         Epoch 58/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5200
         Epoch 59/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5145
         Epoch 60/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5143
         Epoch 61/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5180
         Epoch 62/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5200
         Epoch 63/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5174
         Epoch 64/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5170
         Epoch 65/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5189
         Epoch 66/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5166
         Epoch 67/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5190
         Epoch 68/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5153
         Epoch 69/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5147
         Epoch 70/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5120
         Epoch 71/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5176
         Epoch 72/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5182
         Epoch 73/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5123
         Epoch 74/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5148
         Epoch 75/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5149
         Epoch 76/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5159
         Epoch 77/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5157
         Epoch 78/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5170
         Epoch 79/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5151
         Epoch 80/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5184
         Epoch 81/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5149
         Epoch 82/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5169
         Epoch 83/150
         350/350 [==============================] - 0s 1ms/step - loss: 0.5120
```

```
Epoch 84/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5136
Epoch 85/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5133
Epoch 86/150
350/350 [==============================] - 0s 997us/step - loss: 0.5158
Epoch 87/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5113
Epoch 88/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5187
Epoch 89/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5138
Epoch 90/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5168
Epoch 91/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5172
Epoch 92/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5137
Epoch 93/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5185
Epoch 94/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5173
Epoch 95/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5156
Epoch 96/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5158
Epoch 97/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5131
Epoch 98/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5159
Epoch 99/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5141
Epoch 100/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5156
Epoch 101/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5143
Epoch 102/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5159
Epoch 103/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5137
Epoch 104/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5148
Epoch 105/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5149
Epoch 106/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5131
Epoch 107/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5160
Epoch 108/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5142
Epoch 109/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5198
Epoch 110/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5193
Epoch 111/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5134
Epoch 112/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5127
Epoch 113/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5117
Epoch 114/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5191
Epoch 115/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5130
Epoch 116/150
```

```
350/350 [==============================] - 0s 1ms/step - loss: 0.5193
Epoch 117/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5120
Epoch 118/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5182
Epoch 119/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5178
Epoch 120/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5168
Epoch 121/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5057
Epoch 122/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5168
Epoch 123/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5159
Epoch 124/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5164
Epoch 125/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5111
Epoch 126/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5137
Epoch 127/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5137
Epoch 128/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5152
Epoch 129/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5137
Epoch 130/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5124
Epoch 131/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5164
Epoch 132/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5145
Epoch 133/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5149
Epoch 134/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5201
Epoch 135/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5130
Epoch 136/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5176
Epoch 137/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5131
Epoch 138/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5134
Epoch 139/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5120
Epoch 140/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5118
Epoch 141/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5131
Epoch 142/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5157
Epoch 143/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5196
Epoch 144/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5138
Epoch 145/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5121
Epoch 146/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5160
Epoch 147/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5139
Epoch 148/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5102
```

```
Epoch 149/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5115
Epoch 150/150
350/350 [==============================] - 0s 1ms/step - loss: 0.5159
```

Model Summary

ROC Curve

AUC ROC Score : 0.8438255063779051

```
In [108…  eval_model(result_42[0], result_42[1], result_42[2], 0.5)
```

```
              precision    recall  f1-score   support
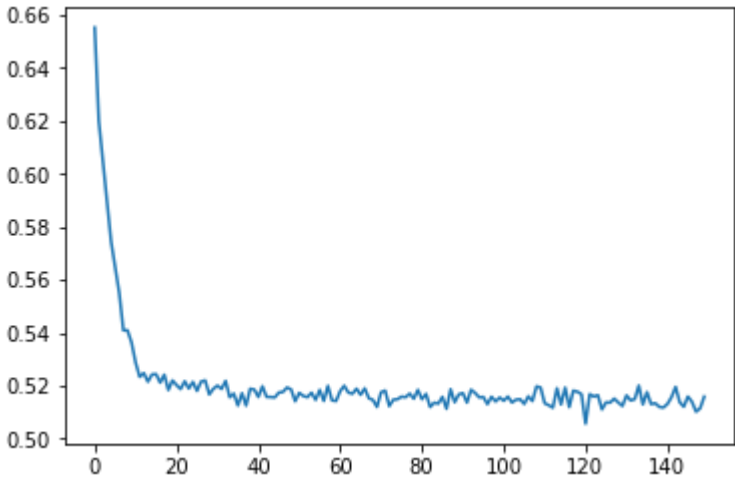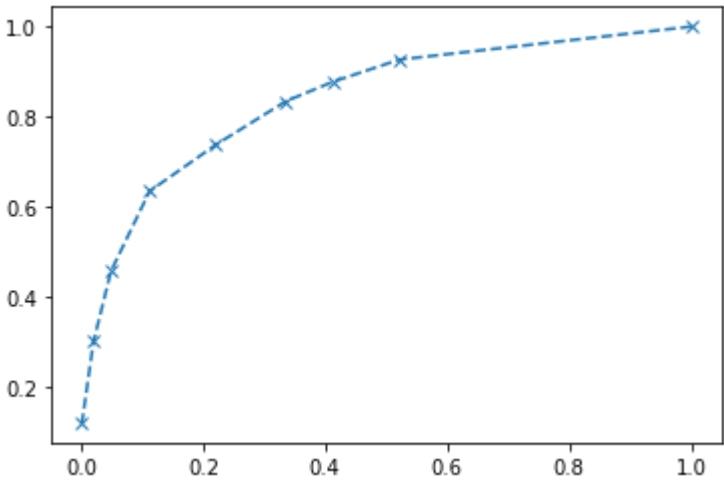
           0       0.92      0.78      0.84      2373
           1       0.47      0.74      0.57       627

    accuracy                           0.77      3000
   macro avg       0.69      0.76      0.71      3000
weighted avg       0.82      0.77      0.79      3000
```

Assumptions

Once again, we slightly increased the complexity from two hidden layer to three hidden layers. The AUC ROC scores reduced once more. The AUC ROC score for RandomOverSampler and SMOTE are almost the same.

    0.58 - Base (0.2)

    0.70 - RandomOverSampler (0.4)

    0.74 - SMOTE (0.5)

Conclusion

The goal of this project is to create a model that would predict the likelihood of a bank customer exiting the bank.

Version 1.0

EDA and preprocessing. Base models with and without oversampling created.

Version 2.0

Definitions created.
Seaborn plotted within grids.

Version 3.0

Identifying threshold using AUC-ROC. The value picked would have a high TPR value with a low FPR.

Version 4.0

Ran multiple iterations to achieve the best model.

Version 5.0

Repeated running the same models, however, dropout was added.