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Reg No:- RA1911003010325

Machine Learning - Core Concepts with Applications

ASSIGNMENT - 5

Classification using Decision Trees and Random Forest

DATASET:- RED WINE QUALITY CLASSIFICATION

Importing Libraries and Reading the Dataset

In [6]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.metrics import accuracy_score
from sklearn.metrics import mean_squared_error
from sklearn.model_selection import cross_val_score
from sklearn.metrics import confusion_matrix
from collections import Counter
from IPython.core.display import display, HTML
sns.set_style('darkgrid')
```

In [7]:
```
dataset = pd.read_csv('winequality-red.csv')
dataset.head()
```

Out[7]:

	fixed acidity	volatile acidity	citric acid	residual sugar	chlorides	free sulfur dioxide	total sulfur dioxide	density	pH	sulphates	alcohol	quality
0	7.4	0.70	0.00	1.9	0.076	11.0	34.0	0.9978	3.51	0.56	9.4	5
1	7.8	0.88	0.00	2.6	0.098	25.0	67.0	0.9968	3.20	0.68	9.8	5
2	7.8	0.76	0.04	2.3	0.092	15.0	54.0	0.9970	3.26	0.65	9.8	5
3	11.2	0.28	0.56	1.9	0.075	17.0	60.0	0.9980	3.16	0.58	9.8	6
4	7.4	0.70	0.00	1.9	0.076	11.0	34.0	0.9978	3.51	0.56	9.4	5

Data Visualization and Preprocessing

In [8]:
```
dataset.isnull().sum()
```

Out[8]:
```
fixed acidity           0
volatile acidity        0
citric acid             0
residual sugar          0
chlorides               0
free sulfur dioxide     0
total sulfur dioxide    0
density                 0
pH                      0
sulphates               0
alcohol                 0
quality                 0
dtype: int64
```

In [9]:
```
bins = (2, 6.5, 8)
labels = ['bad', 'good']
dataset['quality'] = pd.cut(x = dataset['quality'], bins = bins, labels = labels)
```

In [10]:
```
dataset['quality'].value_counts()
```

Out[10]:
```
bad     1382
good     217
Name: quality, dtype: int64
```

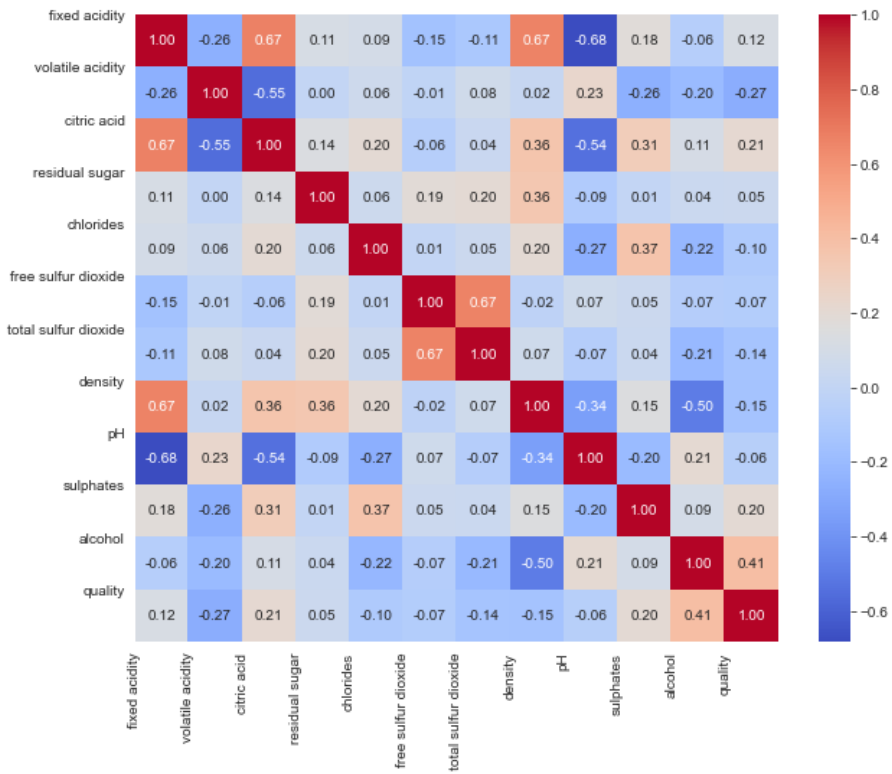
In [11]:
```
from sklearn.preprocessing import LabelEncoder
labelencoder_y = LabelEncoder()
dataset['quality'] = labelencoder_y.fit_transform(dataset['quality'])
```

In [12]:
```
dataset.head()
```

Out[12]:

	fixed acidity	volatile acidity	citric acid	residual sugar	chlorides	free sulfur dioxide	total sulfur dioxide	density	pH	sulphates	alcohol	quality
0	7.4	0.70	0.00	1.9	0.076	11.0	34.0	0.9978	3.51	0.56	9.4	0
1	7.8	0.88	0.00	2.6	0.098	25.0	67.0	0.9968	3.20	0.68	9.8	0
2	7.8	0.76	0.04	2.3	0.092	15.0	54.0	0.9970	3.26	0.65	9.8	0
3	11.2	0.28	0.56	1.9	0.075	17.0	60.0	0.9980	3.16	0.58	9.8	0
4	7.4	0.70	0.00	1.9	0.076	11.0	34.0	0.9978	3.51	0.56	9.4	0

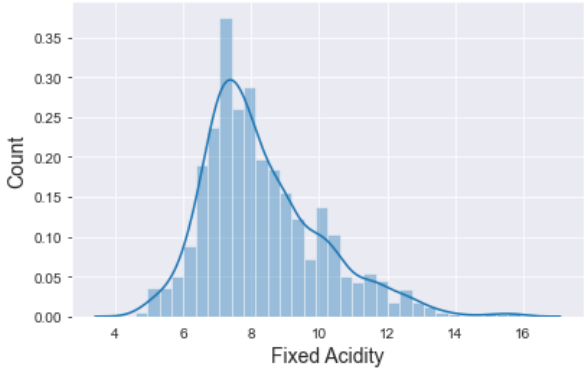
In [13]:
```
corr = dataset.corr()
#Plot figsize
fig, ax = plt.subplots(figsize=(10, 8))
#Generate Heat Map, allow annotations and place floats in map
sns.heatmap(corr, cmap='coolwarm', annot=True, fmt=".2f")
#Apply xticks
plt.xticks(range(len(corr.columns)), corr.columns);
#Apply yticks
plt.yticks(range(len(corr.columns)), corr.columns)
#show plot
plt.show()
```

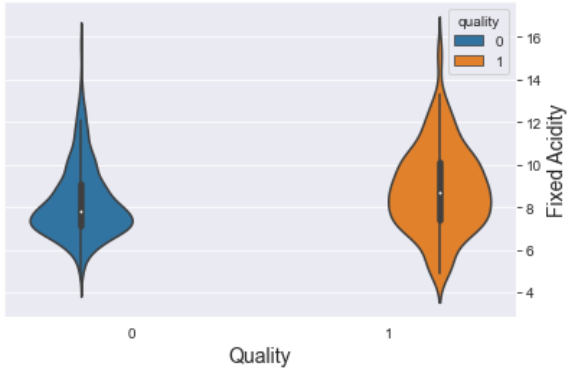


In [14]:

```
f, axes = plt.subplots(1,2,figsize=(14,4))

sns.distplot(dataset['fixed acidity'], ax = axes[0])
axes[0].set_xlabel('Fixed Acidity', fontsize=14)
axes[0].set_ylabel('Count', fontsize=14)
axes[0].yaxis.tick_left()

sns.violinplot(x = 'quality', y = 'fixed acidity', data = dataset, hue = 'quality',ax = axes[1])
axes[1].set_xlabel('Quality', fontsize=14)
axes[1].set_ylabel('Fixed Acidity', fontsize=14)
axes[1].yaxis.set_label_position("right")
axes[1].yaxis.tick_right()

plt.show()
```

```
/Users/harshilagarwal/opt/anaconda3/lib/python3.8/site-packages/seaborn/distributions.py:2551: FutureWarning: `distplot` is a deprecated function and will be removed in a future versio
n. Please adapt your code to use either `displot` (a figure-level function with similar flexibility) or `histplot` (an axes-level function for histograms).
  warnings.warn(msg, FutureWarning)
```





In [15]:
```
f, axes = plt.subplots(1,2,figsize=(14,4))

sns.distplot(dataset['volatile acidity'], ax = axes[0])
axes[0].set_xlabel('Volatile Acidity', fontsize=14)
axes[0].set_ylabel('Count', fontsize=14)
axes[0].yaxis.tick_left()

sns.violinplot(x = 'quality', y = 'volatile acidity', data = dataset, hue = 'quality',ax = axes[1])
axes[1].set_xlabel('Quality', fontsize=14)
axes[1].set_ylabel('Volatile Acidity', fontsize=14)
axes[1].yaxis.set_label_position("right")
axes[1].yaxis.tick_right()

plt.show()
```

```
/Users/harshilagarwal/opt/anaconda3/lib/python3.8/site-packages/seaborn/distributions.py:2551: FutureWarning: `distplot` is a deprecated function and will be removed in a future versio
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  warnings.warn(msg, FutureWarning)
```

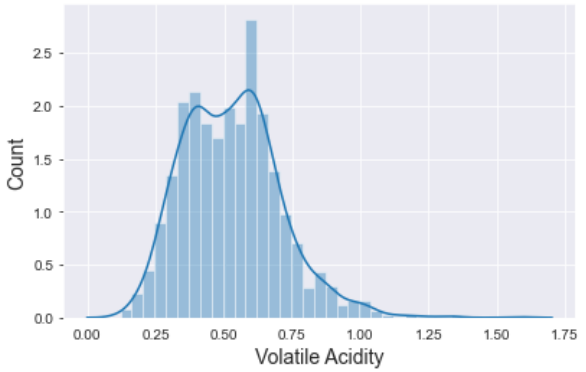

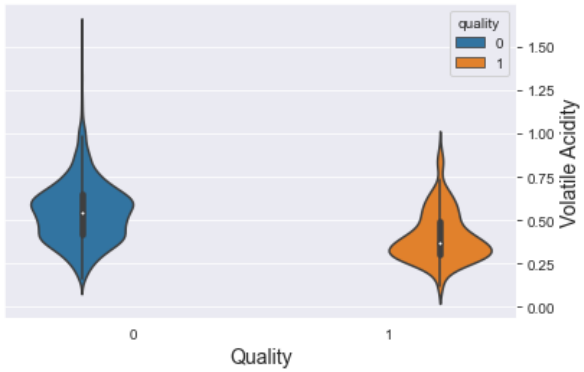

In [16]:
```
f, axes = plt.subplots(1,2,figsize=(14,4))

sns.distplot(dataset['citric acid'], ax = axes[0])
axes[0].set_xlabel('Citric Acid', fontsize=14)
axes[0].set_ylabel('Count', fontsize=14)
axes[0].yaxis.tick_left()

sns.boxenplot(x = 'quality', y = 'citric acid', data = dataset, hue = 'quality',ax = axes[1])
axes[1].set_xlabel('Quality', fontsize=14)
axes[1].set_ylabel('Citric Acid', fontsize=14)
axes[1].yaxis.set_label_position("right")
axes[1].yaxis.tick_right()

plt.show()
```

```
/Users/harshilagarwal/opt/anaconda3/lib/python3.8/site-packages/seaborn/distributions.py:2551: FutureWarning: `distplot` is a deprecated function and will be removed in a future versio
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  warnings.warn(msg, FutureWarning)
```

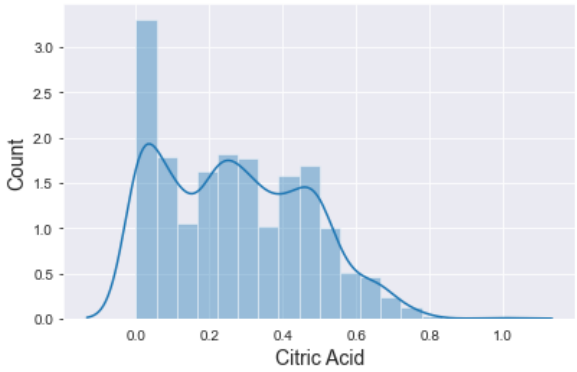

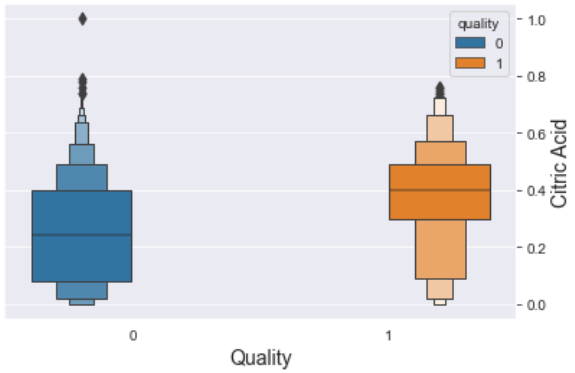

In [17]:
```
f, axes = plt.subplots(1,2,figsize=(14,4))

sns.distplot(dataset['residual sugar'], ax = axes[0])
axes[0].set_xlabel('Residual Sugar', fontsize=14)
axes[0].set_ylabel('Count', fontsize=14)
axes[0].yaxis.tick_left()

sns.violinplot(x = 'quality', y = 'residual sugar', data = dataset, hue = 'quality',ax = axes[1])
axes[1].set_xlabel('Quality', fontsize=14)
axes[1].set_ylabel('Residual Sugar', fontsize=14)
axes[1].yaxis.set_label_position("right")
axes[1].yaxis.tick_right()

plt.show()
```

```
/Users/harshilagarwal/opt/anaconda3/lib/python3.8/site-packages/seaborn/distributions.py:2551: FutureWarning: `distplot` is a deprecated function and will be removed in a future versio
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  warnings.warn(msg, FutureWarning)
```

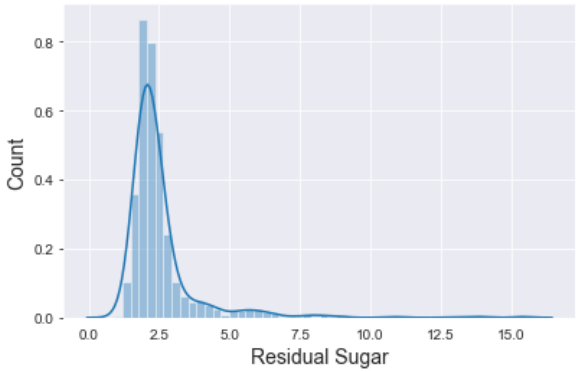

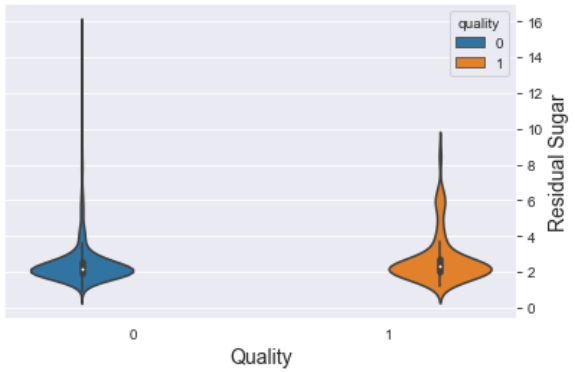

In [18]:
```
f, axes = plt.subplots(1,2,figsize=(14,4))

sns.distplot(dataset['chlorides'], ax = axes[0])
axes[0].set_xlabel('Chlorides', fontsize=14)
axes[0].set_ylabel('Count', fontsize=14)
axes[0].yaxis.tick_left()

sns.violinplot(x = 'quality', y = 'chlorides', data = dataset, hue = 'quality',ax = axes[1])
axes[1].set_xlabel('Quality', fontsize=14)
axes[1].set_ylabel('Chlorides', fontsize=14)
axes[1].yaxis.set_label_position("right")
axes[1].yaxis.tick_right()
```

```
plt.show()
```

```
/Users/harshilagarwal/opt/anaconda3/lib/python3.8/site-packages/seaborn/distributions.py:2551: FutureWarning: `distplot` is a deprecated function and will be removed in a future versio
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  warnings.warn(msg, FutureWarning)
```

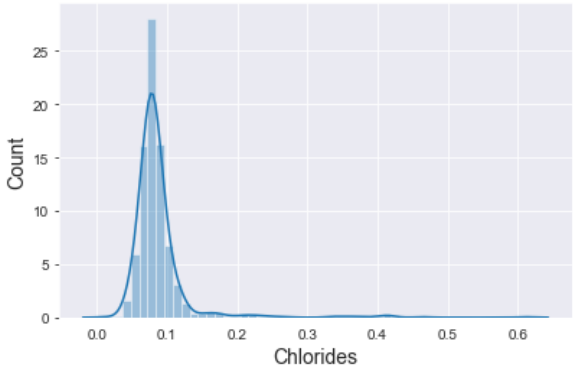

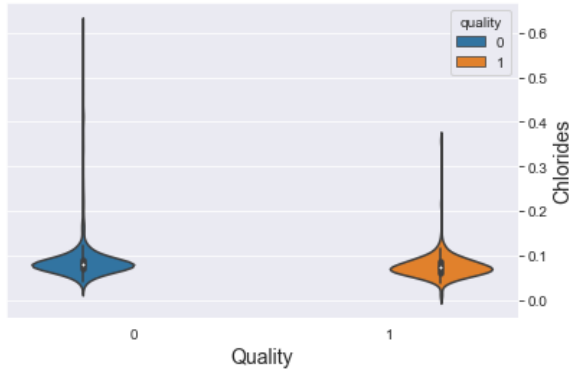

In [19]:
```
f, axes = plt.subplots(2,2,figsize=(14,8))

sns.distplot(dataset['free sulfur dioxide'], ax = axes[0,0])
axes[0,0].set_xlabel('Free Sulfur Dioxide', fontsize=14)
axes[0,0].set_ylabel('Count', fontsize=14)
axes[0,0].yaxis.tick_left()

sns.boxenplot(x = 'quality', y = 'free sulfur dioxide', data = dataset, hue = 'quality',ax = axes[0,1])
axes[0,1].set_xlabel('Quality', fontsize=14)
axes[0,1].set_ylabel('Free Sulfur Dioxide', fontsize=14)
axes[0,1].yaxis.set_label_position("right")
axes[0,1].yaxis.tick_right()

sns.distplot(dataset['total sulfur dioxide'], ax = axes[1,0])
axes[1,0].set_xlabel('Total Sulfur Dioxide', fontsize=14)
axes[1,0].set_ylabel('Count', fontsize=14)
axes[1,0].yaxis.tick_left()

sns.boxenplot(x = 'quality', y = 'total sulfur dioxide', data = dataset, hue = 'quality',ax = axes[1,1])
axes[1,1].set_xlabel('Quality', fontsize=14)
axes[1,1].set_ylabel('Total Sulfur Dioxide', fontsize=14)
axes[1,1].yaxis.set_label_position("right")
axes[1,1].yaxis.tick_right()

plt.show()
```

```
/Users/harshilagarwal/opt/anaconda3/lib/python3.8/site-packages/seaborn/distributions.py:2551: FutureWarning: `distplot` is a deprecated function and will be removed in a future versio
n. Please adapt your code to use either `displot` (a figure-level function with similar flexibility) or `histplot` (an axes-level function for histograms).
  warnings.warn(msg, FutureWarning)
/Users/harshilagarwal/opt/anaconda3/lib/python3.8/site-packages/seaborn/distributions.py:2551: FutureWarning: `distplot` is a deprecated function and will be removed in a future versio
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  warnings.warn(msg, FutureWarning)
```

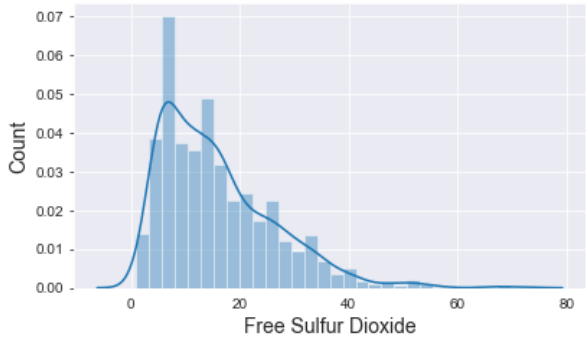

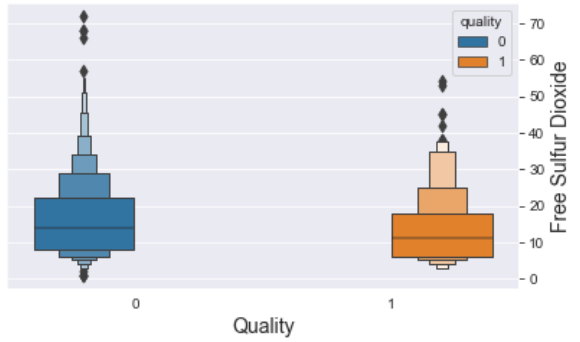

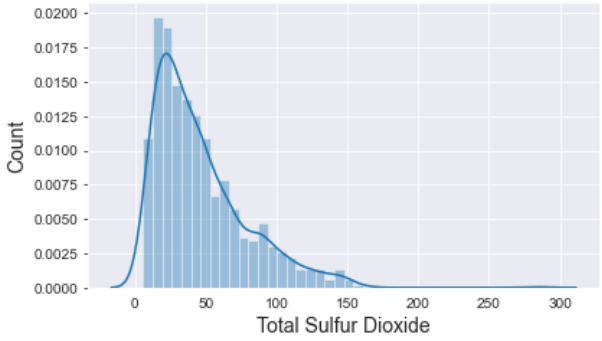

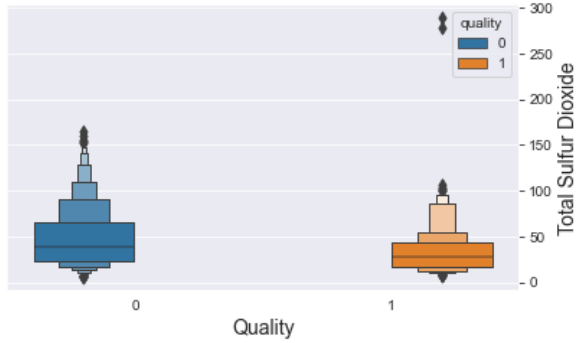

In [20]:
```
f, axes = plt.subplots(1,2,figsize=(14,4))

sns.distplot(dataset['density'], ax = axes[0])
axes[0].set_xlabel('Density', fontsize=14)
axes[0].set_ylabel('Count', fontsize=14)
axes[0].yaxis.tick_left()

sns.violinplot(x = 'quality', y = 'density', data = dataset, hue = 'quality',ax = axes[1])
axes[1].set_xlabel('Quality', fontsize=14)
axes[1].set_ylabel('Density', fontsize=14)
axes[1].yaxis.set_label_position("right")
axes[1].yaxis.tick_right()

plt.show()
```

```
/Users/harshilagarwal/opt/anaconda3/lib/python3.8/site-packages/seaborn/distributions.py:2551: FutureWarning: `distplot` is a deprecated function and will be removed in a future versio
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  warnings.warn(msg, FutureWarning)
```

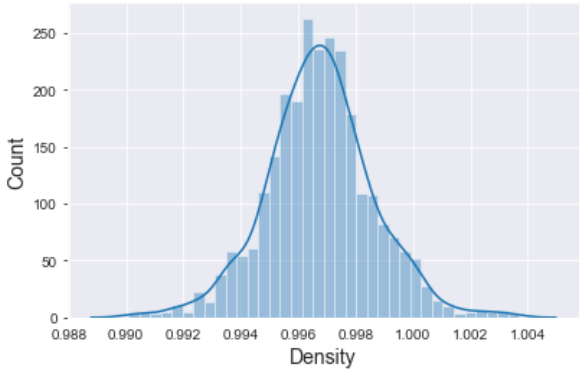

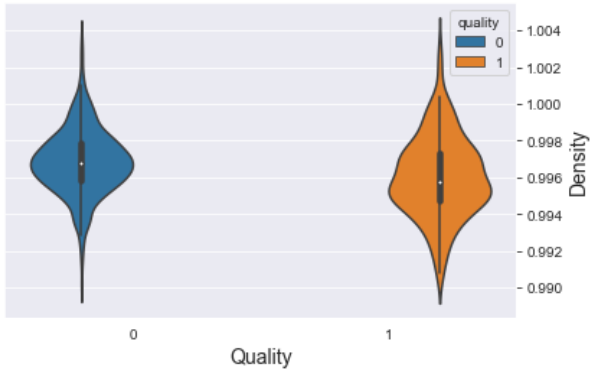

In [21]:
```
f, axes = plt.subplots(1,2,figsize=(14,4))
```

```
sns.distplot(dataset['pH'], ax = axes[0])
axes[0].set_xlabel('pH', fontsize=14)
axes[0].set_ylabel('Count', fontsize=14)
axes[0].yaxis.tick_left()

sns.violinplot(x = 'quality', y = 'pH', data = dataset, hue = 'quality',ax = axes[1])
axes[1].set_xlabel('Quality', fontsize=14)
axes[1].set_ylabel('pH', fontsize=14)
axes[1].yaxis.set_label_position("right")
axes[1].yaxis.tick_right()

plt.show()
```

```
/Users/harshilagarwal/opt/anaconda3/lib/python3.8/site-packages/seaborn/distributions.py:2551: FutureWarning: `distplot` is a deprecated function and will be removed in a future versio
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  warnings.warn(msg, FutureWarning)
```

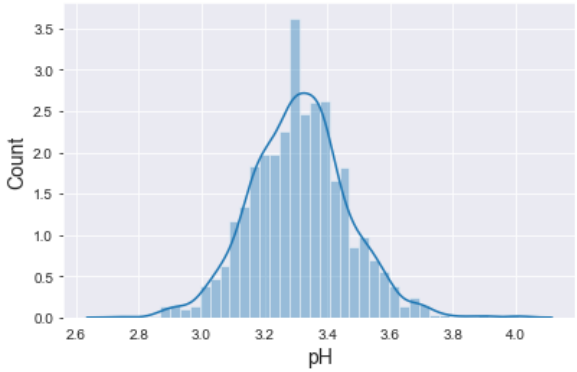

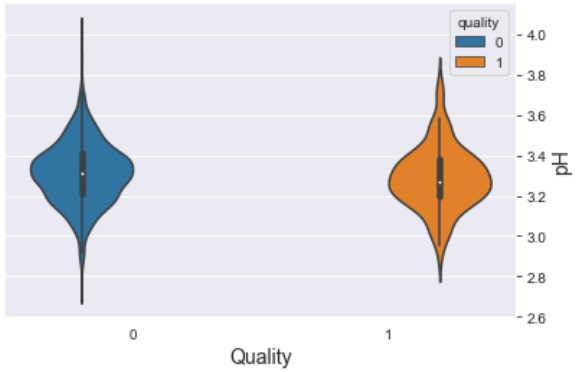

In [22]:

```
f, axes = plt.subplots(1,2,figsize=(14,4))

sns.distplot(dataset['sulphates'], ax = axes[0])
axes[0].set_xlabel('Sulphates', fontsize=14)
axes[0].set_ylabel('Count', fontsize=14)
axes[0].yaxis.tick_left()

sns.violinplot(x = 'quality', y = 'sulphates', data = dataset, hue = 'quality',ax = axes[1])
axes[1].set_xlabel('Quality', fontsize=14)
axes[1].set_ylabel('Sulphates', fontsize=14)
axes[1].yaxis.set_label_position("right")
axes[1].yaxis.tick_right()

plt.show()
```

```
/Users/harshilagarwal/opt/anaconda3/lib/python3.8/site-packages/seaborn/distributions.py:2551: FutureWarning: `distplot` is a deprecated function and will be removed in a future versio
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  warnings.warn(msg, FutureWarning)
```

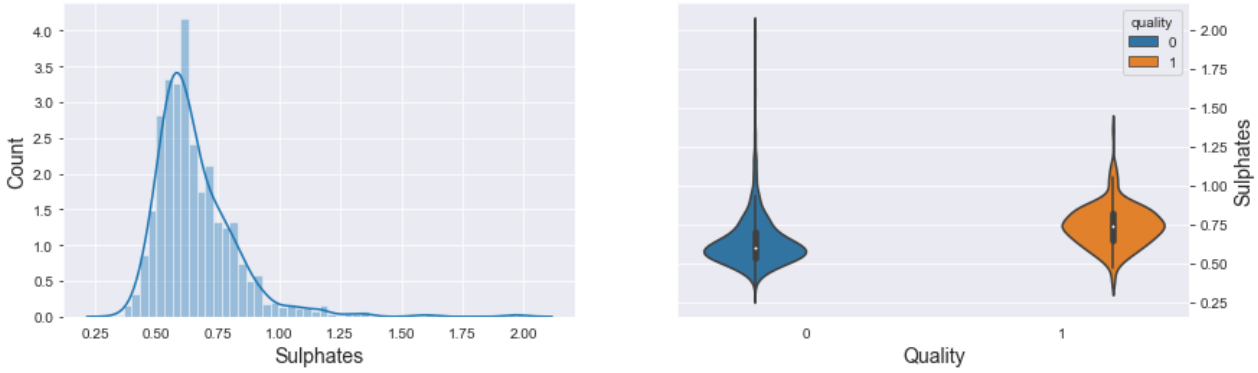

In [23]:
```
f, axes = plt.subplots(1,2,figsize=(14,4))

sns.distplot(dataset['alcohol'], ax = axes[0])
axes[0].set_xlabel('Alcohol', fontsize=14)
axes[0].set_ylabel('Count', fontsize=14)
axes[0].yaxis.tick_left()

sns.violinplot(x = 'quality', y = 'alcohol', data = dataset, hue = 'quality',ax = axes[1])
axes[1].set_xlabel('Quality', fontsize=14)
axes[1].set_ylabel('Alcohol', fontsize=14)
axes[1].yaxis.set_label_position("right")
axes[1].yaxis.tick_right()

plt.show()
```

```
/Users/harshilagarwal/opt/anaconda3/lib/python3.8/site-packages/seaborn/distributions.py:2551: FutureWarning: `distplot` is a deprecated function and will be removed in a future versio
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  warnings.warn(msg, FutureWarning)
```
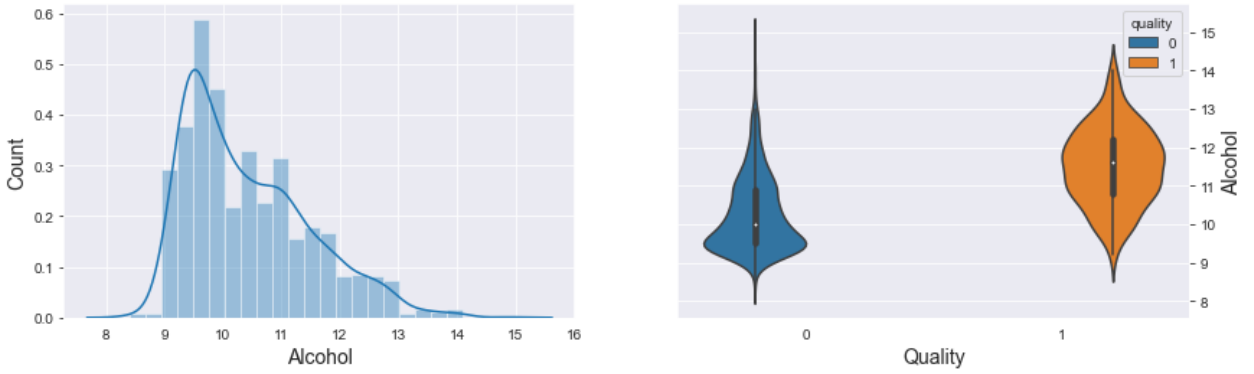



In [24]:
```
dataset['quality'].value_counts()
```

Out[24]:
```
0    1382
1     217
Name: quality, dtype: int64
```

In [25]:
```
X = dataset.drop('quality', axis = 1).values
y = dataset['quality'].values.reshape(-1,1)
```

In [26]:
```
# Splitting the dataset into the Training set and Test set
from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size = 0.2, random_state = 42)
```

In [27]:
```
print("Shape of X_train: ",X_train.shape)
```

```
print("Shape of X_test: ", X_test.shape)
print("Shape of y_train: ",y_train.shape)
print("Shape of y_test",y_test.shape)
```

```
Shape of X_train:  (1279, 11)
Shape of X_test:  (320, 11)
Shape of y_train:  (1279, 1)
Shape of y_test (320, 1)
```

Classification Models

In [28]:
```
# Feature Scaling
from sklearn.preprocessing import StandardScaler
sc = StandardScaler()
X_train_scaled = sc.fit_transform(X_train)
X_test_scaled = sc.transform(X_test)
```

Decision Tree Classification

In [29]:
```
# Fitting classifier to the Training set
from sklearn.tree import DecisionTreeClassifier
classifier_dt = DecisionTreeClassifier(criterion = 'gini', max_features=6, max_leaf_nodes=400, random_state = 33)
classifier_dt.fit(X_train_scaled, y_train.ravel())
```

Out[29]:
```
DecisionTreeClassifier(max_features=6, max_leaf_nodes=400, random_state=33)
```

In [30]:
```
# Predicting Cross Validation Score
cv_dt = cross_val_score(estimator = classifier_dt, X = X_train_scaled, y = y_train.ravel(), cv = 10)
print("CV: ", cv_dt.mean())

y_pred_dt_train = classifier_dt.predict(X_train_scaled)
accuracy_dt_train = accuracy_score(y_train, y_pred_dt_train)
print("Training set: ", accuracy_dt_train)

y_pred_dt_test = classifier_dt.predict(X_test_scaled)
accuracy_dt_test = accuracy_score(y_test, y_pred_dt_test)
print("Test set: ", accuracy_dt_test)
```

```
CV:  0.8960014763779528
Training set:  1.0
Test set:  0.878125
```

In [31]:
```
confusion_matrix(y_test, y_pred_dt_test)
```

Out[31]:
```
array([[252,  21],
       [ 18,  29]])
```

In [32]:
```
tp_dt = confusion_matrix(y_test, y_pred_dt_test)[0,0]
fp_dt = confusion_matrix(y_test, y_pred_dt_test)[0,1]
tn_dt = confusion_matrix(y_test, y_pred_dt_test)[1,1]
fn_dt = confusion_matrix(y_test, y_pred_dt_test)[1,0]
```

Random Forest Classification

In [33]:
```
# Fitting Random Forest Classification to the Training set
from sklearn.ensemble import RandomForestClassifier
classifier_rf = RandomForestClassifier(criterion = 'entropy', max_features = 4, n_estimators = 800, random_state=33)
classifier_rf.fit(X_train_scaled, y_train.ravel())
```

Out[33]:
```
RandomForestClassifier(criterion='entropy', max_features=4, n_estimators=800,
                       random_state=33)
```

In [34]:
```
# Predicting Cross Validation Score
cv_rf = cross_val_score(estimator = classifier_rf, X = X_train_scaled, y = y_train.ravel(), cv = 10)
print("CV: ", cv_rf.mean())
```

```
y_pred_rf_train = classifier_rf.predict(X_train_scaled)
accuracy_rf_train = accuracy_score(y_train, y_pred_rf_train)
print("Training set: ", accuracy_rf_train)

y_pred_rf_test = classifier_rf.predict(X_test_scaled)
accuracy_rf_test = accuracy_score(y_test, y_pred_rf_test)
print("Test set: ", accuracy_rf_test)
```

```
CV:  0.9140194389763779
Training set:  1.0
Test set:  0.9125
```

In [35]:
```
confusion_matrix(y_test, y_pred_rf_test)
```

Out[35]:
```
array([[267,   6],
       [ 22,  25]])
```

In [36]:
```
tp_rf = confusion_matrix(y_test, y_pred_rf_test)[0,0]
fp_rf = confusion_matrix(y_test, y_pred_rf_test)[0,1]
tn_rf = confusion_matrix(y_test, y_pred_rf_test)[1,1]
fn_rf = confusion_matrix(y_test, y_pred_rf_test)[1,0]
```

OBSERVATION

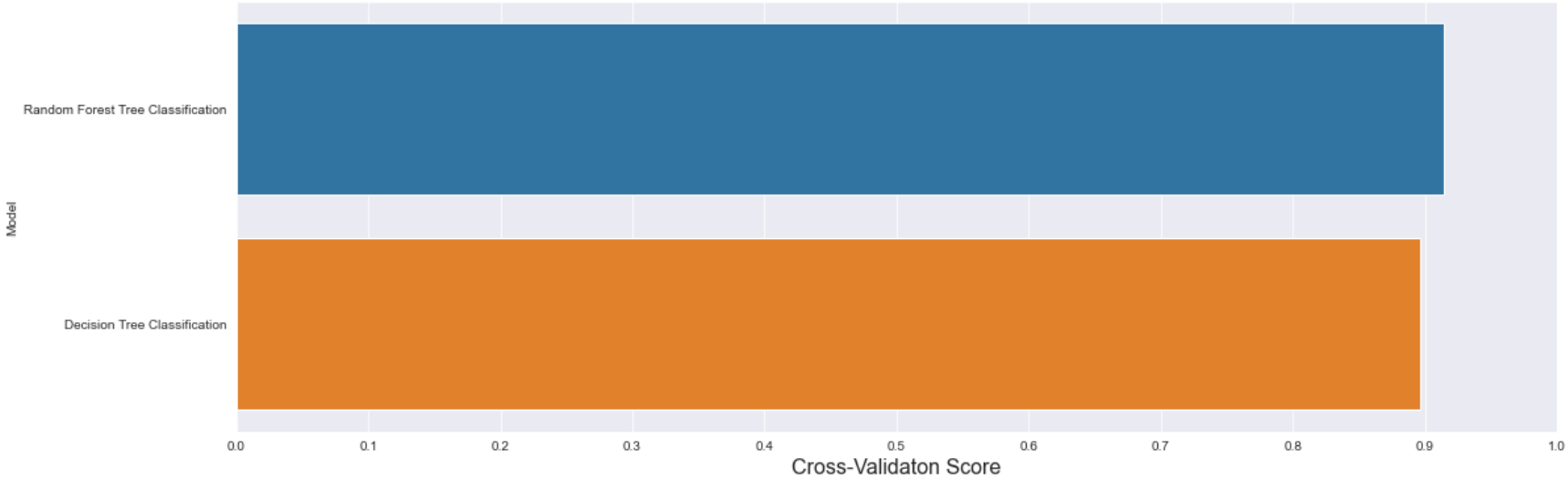
In [37]:
```
models = [('Decision Tree Classification', tp_dt, fp_dt, tn_dt, fn_dt, accuracy_dt_train, accuracy_dt_test, cv_dt.mean()),
          ('Random Forest Tree Classification', tp_rf, fp_rf, tn_rf, fn_rf, accuracy_rf_train, accuracy_rf_test, cv_rf.mean())
         ]
```

In [38]:
```
predict = pd.DataFrame(data = models, columns=['Model', 'True Positive', 'False Positive', 'True Negative',
                                               'False Negative', 'Accuracy(training)', 'Accuracy(test)',
                                               'Cross-Validation'])
predict
```

Out[38]:

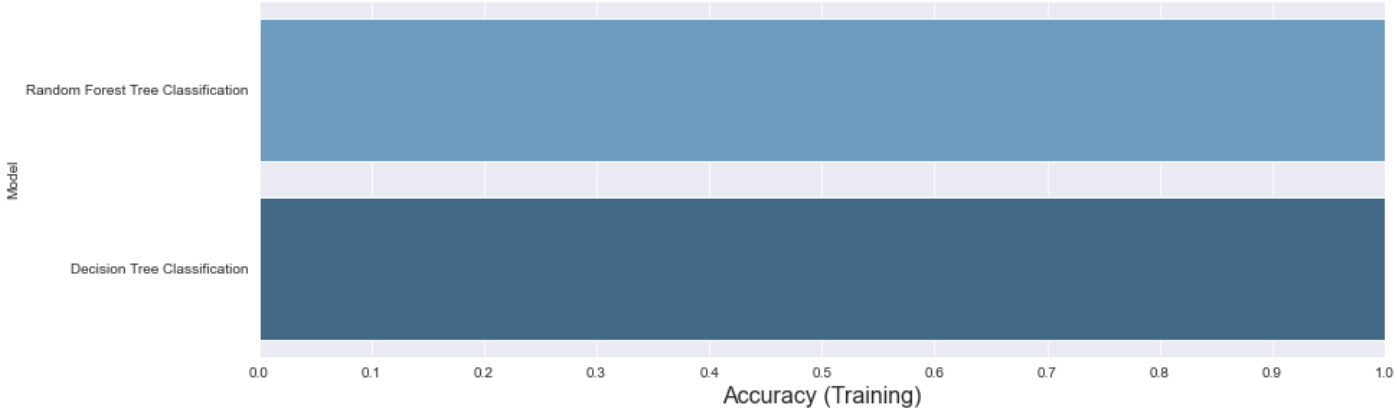
	Model	True Positive	False Positive	True Negative	False Negative	Accuracy(training)	Accuracy(test)	Cross-Validation
0	Decision Tree Classification	252	21	29	18	1.0	0.878125	0.896001
1	Random Forest Tree Classification	267	6	25	22	1.0	0.912500	0.914019

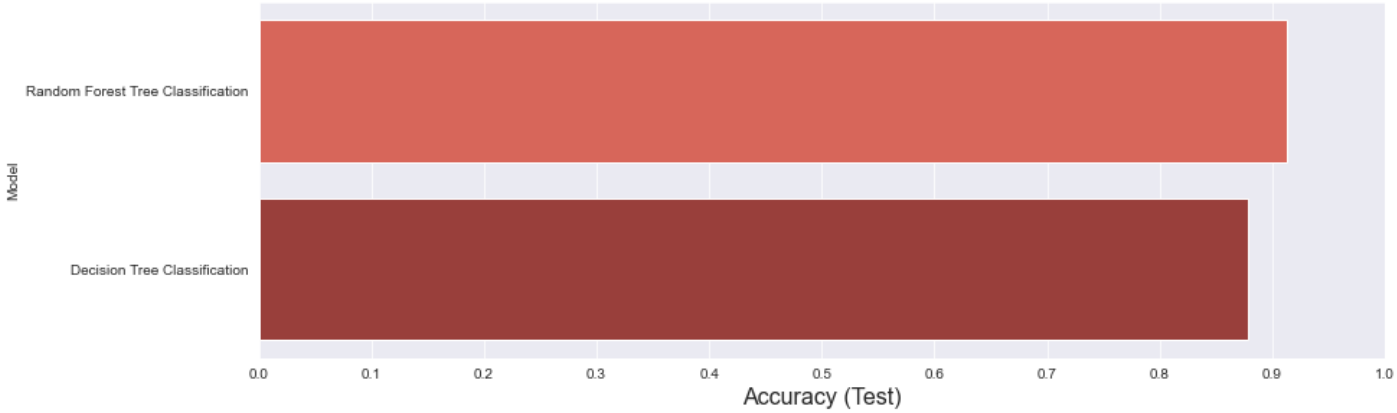
In [39]:
```
f, axe = plt.subplots(1,1, figsize=(18,6))

predict.sort_values(by=['Cross-Validation'], ascending=False, inplace=True)

sns.barplot(x='Cross-Validation', y='Model', data = predict, ax = axe)
#axes[0].set(xlabel='Region', ylabel='Charges')
axe.set_xlabel('Cross-Validaton Score', size=16)
axe.set_ylabel('Model')
axe.set_xlim(0,1.0)
axe.set_xticks(np.arange(0, 1.1, 0.1))
plt.show()
```



In [40]:

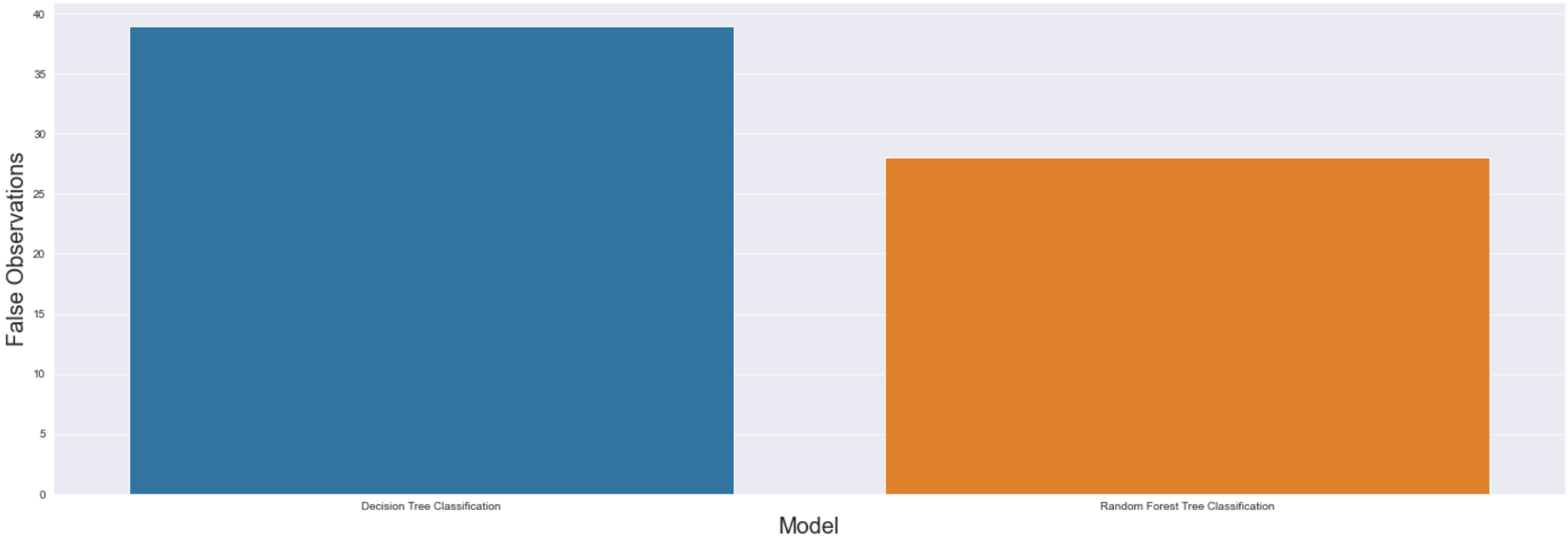
```
f, axes = plt.subplots(2,1, figsize=(14,10))

predict.sort_values(by=['Accuracy(training)'], ascending=False, inplace=True)

sns.barplot(x='Accuracy(training)', y='Model', data = predict, palette='Blues_d', ax = axes[0])
#axes[0].set(xlabel='Region', ylabel='Charges')
axes[0].set_xlabel('Accuracy (Training)', size=16)
axes[0].set_ylabel('Model')
axes[0].set_xlim(0,1.0)
axes[0].set_xticks(np.arange(0, 1.1, 0.1))

predict.sort_values(by=['Accuracy(test)'], ascending=False, inplace=True)

sns.barplot(x='Accuracy(test)', y='Model', data = predict, palette='Reds_d', ax = axes[1])
#axes[0].set(xlabel='Region', ylabel='Charges')
axes[1].set_xlabel('Accuracy (Test)', size=16)
axes[1].set_ylabel('Model')
axes[1].set_xlim(0,1.0)
axes[1].set_xticks(np.arange(0, 1.1, 0.1))

plt.show()
```





In [41]:

```
predict.sort_values(by=(['Accuracy(test)']), ascending=True, inplace=True)

f, axe = plt.subplots(1,1, figsize=(24,8))
sns.barplot(x = predict['Model'], y=predict['False Positive'] + predict['False Negative'], ax = axe)
axe.set_xlabel('Model', size=20)
axe.set_ylabel('False Observations', size=20)

plt.show()
```


False Observations
40
35
30
25
20
15
10
5
0
Decision Tree Classification
Random Forest Tree Classification
Model