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

%matplotlib inline
```

In [ ]:
```
df=pd.read_csv('/content/drive/MyDrive/project ai/UCI Heart Disease Data.csv')
df
```

	id	age	sex	dataset	cp	trestbps	chol
0	1	63	Male	Cleveland	typical angina	145.0	233.0
1	2	67	Male	Cleveland	asymptomatic	160.0	286.0
2	3	67	Male	Cleveland	asymptomatic	120.0	229.0
3	4	37	Male	Cleveland	non-anginal	130.0	250.0
4	5	41	Female	Cleveland	atypical angina	130.0	204.0
...	...	...	...	...	...	...	...
915	916	54	Female	VA Long Beach	asymptomatic	127.0	333.0
916	917	62	Male	VA Long Beach	typical angina	NaN	139.0
917	918	55	Male	VA Long Beach	asymptomatic	122.0	223.0
918	919	58	Male	VA Long Beach	asymptomatic	NaN	385.0
919	920	62	Male	VA Long Beach	atypical angina	120.0	254.0

920 rows × 16 columns

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

	id	age	sex	dataset	cp	trestbps	chol	fb
0	1	63	Male	Cleveland	typical angina	145.0	233.0	True
1	2	67	Male	Cleveland	asymptomatic	160.0	286.0	Fals
2	3	67	Male	Cleveland	asymptomatic	120.0	229.0	Fals
3	4	37	Male	Cleveland	non-anginal	130.0	250.0	Fals
4	5	41	Female	Cleveland	atypical angina	130.0	204.0	Fals

In [ ]:
```
df.columns.values
```

```
array(['id', 'age', 'sex', 'dataset', 'cp', 'trestbps', 'chol', 'fbs',
       'restecg', 'thalch', 'exang', 'oldpeak', 'slope', 'ca', 'thal',
       'num'], dtype=object)
```

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

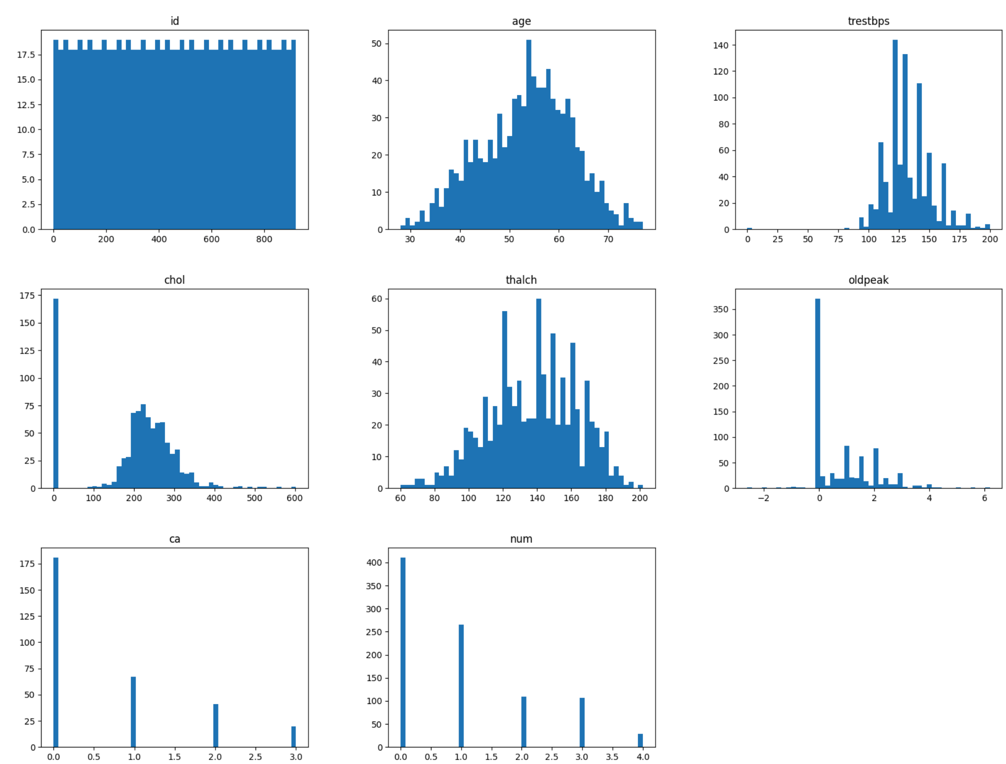
	0
id	0
age	0
sex	0
dataset	0
cp	0
trestbps	59
chol	30
fbs	90
restecg	2
thalch	55
exang	55
oldpeak	62
slope	309
ca	611
thal	486
num	0

dtype: int64

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

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 920 entries, 0 to 919
Data columns (total 16 columns):
 #   Column    Non-Null Count  Dtype  
---  ------    --------------  -----  
 0   id        920 non-null    int64  
 1   age       920 non-null    int64  
 2   sex       920 non-null    object 
 3   dataset   920 non-null    object 
 4   cp        920 non-null    object 
 5   trestbps  861 non-null    float64
 6   chol      890 non-null    float64
 7   fbs       830 non-null    object 
 8   restecg   918 non-null    object 
 9   thalch    865 non-null    float64
 10  exang     865 non-null    object 
 11  oldpeak   858 non-null    float64
 12  slope     611 non-null    object 
 13  ca        309 non-null    float64
 14  thal      434 non-null    object 
 15  num       920 non-null    int64  
dtypes: float64(5), int64(3), object(8)
memory usage: 115.1+ KB
```

In [ ]:
```
df.hist(bins = 50, grid = False, figsize = (20,15));
```



In [ ]:
```
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import LabelEncoder, OneHotEncoder,
StandardScaler, MinMaxScaler
from sklearn.compose import ColumnTransformer
from sklearn.pipeline import Pipeline
```

In [ ]:
```
#handle missing value
missing_counts = df.isna().sum()
print(missing_counts[missing_counts > 0])
```

```
trestbps     59
chol         30
fbs          90
restecg       2
thalch       55
exang        55
oldpeak      62
slope       309
ca          611
thal        486
dtype: int64
```

In [ ]:
```
#Duplicate rows remove
print("Duplicates before:", df.duplicated().sum())
df = df.drop_duplicates().reset_index(drop=True)
print("Shape after dropping duplicates:", df.shape)
```

```
Duplicates before: 0
Shape after dropping duplicates: (920, 16)
```

In [ ]:
```
#Correct data type
if 'oldpeak' in df.columns:
    df['oldpeak'] = df['oldpeak'].astype('float64')
    print(df['oldpeak'].value_counts())
```

```
oldpeak
 0.0    370
 1.0     83
 2.0     76
 1.5     48
 3.0     28
 0.5     19
 1.2     17
 2.5     16
 0.8     15
 1.4     15
 0.6     14
 0.2     14
 1.6     14
 1.8     12
 0.4     10
 0.1      9
 4.0      8
 2.6      7
 2.8      7
 2.2      5
 1.3      5
 0.3      5
 0.7      5
 1.9      5
 1.1      4
 3.6      4
 2.4      4
 0.9      4
 3.4      3
-0.5      2
 3.2      2
 2.3      2
 3.5      2
 1.7      2
-1.0      2
 4.2      2
 2.1      2
 3.1      1
 2.9      1
 6.2      1
 5.6      1
 3.8      1
-1.1      1
 4.4      1
 5.0      1
-2.6      1
-0.1      1
```

```
-1.5      1
-2.0      1
-0.7      1
-0.8      1
-0.9      1
 3.7      1
Name: count, dtype: int64
```

In [ ]:

```
import pandas as pd

df = pd.read_csv("/content/drive/MyDrive/project ai/UCI Heart Disease Data.csv")
print("Dataset Loaded Successfully!")
```

```
Dataset Loaded Successfully!
```

In [ ]:
```
import pandas as pd
from sklearn.preprocessing import LabelEncoder

# Load dataset
df = pd.read_csv("//content/drive/MyDrive/project ai/UCI Heart Disease
Data.csv")

# Categorical columns in your dataset
categorical_cols = ['sex', 'cp', 'fbs', 'restecg', 'exang', 'slope', 'ca',
'thal', 'target']

le = LabelEncoder()

for col in categorical_cols:
    if col in df.columns:

        # 1. Fill missing values first
        df[col] = df[col].fillna(df[col].mode()[0])

        # 2. If string → Label Encode it
        if df[col].dtype == 'object':
            df[col] = le.fit_transform(df[col])

        # 3. Now safely convert to int
        df[col] = df[col].astype(int)

print("✓ All categorical columns encoded successfully!")
```

```
✓ All categorical columns encoded successfully!
```

```
/tmp/ipython-input-3325805646.py:16: FutureWarning: Downcasting
object dtype arrays on .fillna, .ffill, .bfill is deprecated and
will change in a future version. Call
result.infer_objects(copy=False) instead. To opt-in to the future
behavior, set `pd.set_option('future.no_silent_downcasting', True)`
  df[col] = df[col].fillna(df[col].mode()[0])
/tmp/ipython-input-3325805646.py:16: FutureWarning: Downcasting
object dtype arrays on .fillna, .ffill, .bfill is deprecated and
will change in a future version. Call
result.infer_objects(copy=False) instead. To opt-in to the future
behavior, set `pd.set_option('future.no_silent_downcasting', True)`
  df[col] = df[col].fillna(df[col].mode()[0])
```

In [ ]:
```
print(df.columns)
```

```
Index(['id', 'age', 'sex', 'dataset', 'cp', 'trestbps', 'chol', 'fbs',
       'restecg', 'thalch', 'exang', 'oldpeak', 'slope', 'ca', 'thal',
'num'],
      dtype='object')
```

In [ ]:
```
# One-Hot Encoding for multi-class categorical features in UCI Heart Disease
dataset

multi_class_cols = ['cp', 'restecg', 'slope', 'ca', 'thal']

# Keep only valid columns
multi_class_cols = [col for col in multi_class_cols if col in df.columns]

if len(multi_class_cols) > 0:
    print("Applying One-Hot Encoding on:", multi_class_cols)

    from sklearn.preprocessing import OneHotEncoder
    import pandas as pd

    # One-Hot Encoder setup
    ohe = OneHotEncoder(sparse_output=False, drop='first')  # updated for
sklearn 1.2+ compatibility

    # Transform categorical columns
    ohe_array = ohe.fit_transform(df[multi_class_cols])

    # Convert to DataFrame
    ohe_df = pd.DataFrame(
        ohe_array,
        columns=ohe.get_feature_names_out(multi_class_cols),
        index=df.index
    )

    # Drop original categorical columns
    df = df.drop(multi_class_cols, axis=1)

    # Merge encoded features
    df = pd.concat([df, ohe_df], axis=1)

else:
    print("No multi-class categorical columns found for One-Hot Encoding.")
    df.info()
```

```
Applying One-Hot Encoding on: ['cp', 'restecg', 'slope', 'ca', 'thal']
```

In [ ]:
```
from sklearn.preprocessing import StandardScaler

# Select numeric columns after encoding
numeric_cols = df.select_dtypes(include=['int64', 'float64']).columns

# Remove ID column if exists
if 'id' in numeric_cols:
    numeric_cols = numeric_cols.drop('id')

# Remove target column
if 'num' in numeric_cols:
    numeric_cols = numeric_cols.drop('num')

print("Numeric Columns to Scale:", list(numeric_cols))

# Apply StandardScaler
scaler = StandardScaler()
df[numeric_cols] = scaler.fit_transform(df[numeric_cols])

print("Scaling Completed!")
```

```
Numeric Columns to Scale: ['age', 'trestbps', 'chol', 'thalch',
'oldpeak', 'cp_atypical angina', 'cp_non-anginal', 'cp_typical angina',
'restecg_normal', 'restecg_st-t abnormality', 'restecg_nan',
'slope_flat', 'slope_upsloping', 'slope_nan', 'ca_1.0', 'ca_2.0',
'ca_3.0', 'ca_nan', 'thal_normal', 'thal_reversable defect',
'thal_nan']
Scaling Completed!
```

In [ ]:
```
from sklearn.model_selection import train_test_split
target = 'num'
# Remove ID and target from feature list
features = [c for c in df.columns if c not in ['id', 'num']]
# Split features and target
X = df[features]
y = df[target]
# Train-test split (80% train, 20% test)
X_train, X_test, y_train, y_test = train_test_split(
    X, y, test_size=0.2, random_state=42, stratify=y
)
print("Train shape:", X_train.shape, y_train.shape)
print("Test shape:", X_test.shape, y_test.shape)

print("\nTrain class distribution:\n", y_train.value_counts(normalize=True))
print("\nTest class distribution:\n", y_test.value_counts(normalize=True))
```

```
Train shape: (736, 25) (736,)
Test shape: (184, 25) (184,)

Train class distribution:
 num
0    0.447011
1    0.288043
2    0.118207
3    0.116848
4    0.029891
Name: proportion, dtype: float64

Test class distribution:
 num
0    0.445652
1    0.288043
2    0.119565
3    0.114130
4    0.032609
Name: proportion, dtype: float64
```

In [ ]:
```
import pandas as pd
from sklearn.preprocessing import LabelEncoder, OneHotEncoder
# BINARY CATEGORICAL COLUMNS → Label Encoding
binary_cols = ['sex', 'fbs', 'exang']  # update if needed
binary_cols = [c for c in binary_cols if c in df.columns]
if len(binary_cols) > 0:
    print("Label Encoding:", binary_cols)
    le = LabelEncoder()
    for col in binary_cols:
        df[col] = le.fit_transform(df[col].astype(str))
# MULTI-CLASS CATEGORICAL → One-Hot Encoding
multi_class_cols = ['cp', 'restecg', 'slope', 'ca', 'thal']
multi_class_cols = [col for col in multi_class_cols if col in df.columns]

if len(multi_class_cols) > 0:
    print("One-Hot Encoding:", multi_class_cols)

    ohe = OneHotEncoder(sparse_output=False, drop='first')

    ohe_array = ohe.fit_transform(df[multi_class_cols])

    ohe_df = pd.DataFrame(
        ohe_array,
        columns=ohe.get_feature_names_out(multi_class_cols),
        index=df.index
    )

    df = df.drop(multi_class_cols, axis=1)
    df = pd.concat([df, ohe_df], axis=1)
#Check final types
print("\nFinal columns type:")
print(df.dtypes)
```

```
Label Encoding: ['sex', 'fbs', 'exang']

Final columns type:
id                            int64
age                         float64
sex                           int64
dataset                      object
trestbps                    float64
chol                        float64
fbs                           int64
thalch                      float64
exang                         int64
oldpeak                     float64
num                           int64
cp_atypical angina          float64
cp_non-anginal              float64
cp_typical angina           float64
restecg_normal              float64
restecg_st-t abnormality    float64
restecg_nan                 float64
```

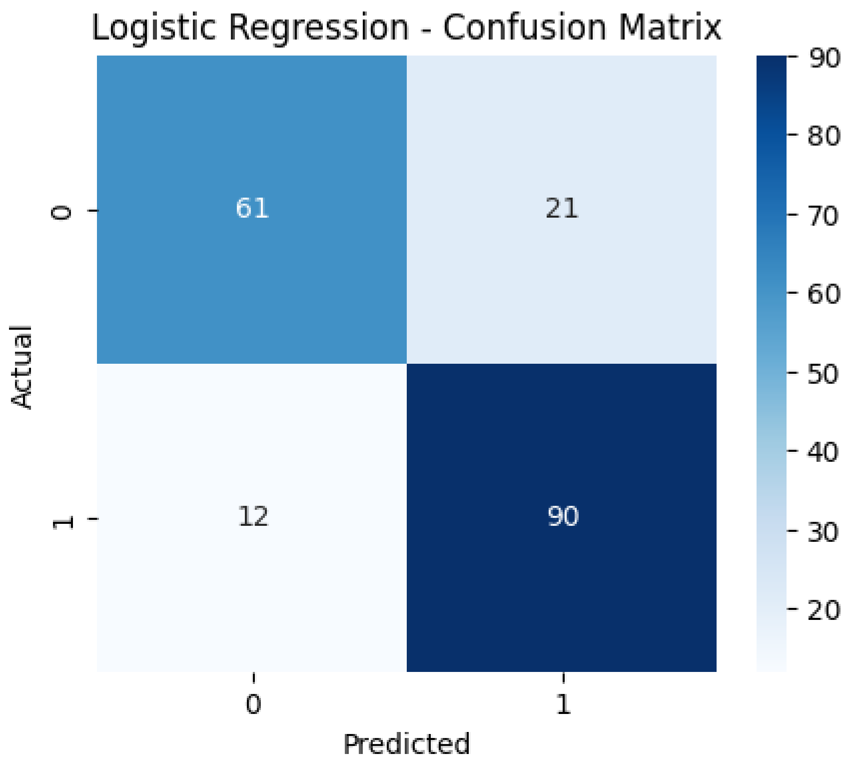
```
slope_flat                  float64
slope_upsloping             float64
slope_nan                   float64
ca_1.0                      float64
ca_2.0                      float64
ca_3.0                      float64
ca_nan                      float64
thal_normal                 float64
thal_reversable defect      float64
thal_nan                    float64
dtype: object
```

In [ ]:
```
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
from sklearn.metrics import accuracy_score
from sklearn.linear_model import LogisticRegression
from sklearn.svm import SVC
from sklearn.neighbors import KNeighborsClassifier
from sklearn.ensemble import RandomForestClassifier
from sklearn.tree import DecisionTreeClassifier

df = pd.read_csv("/content/drive/MyDrive/project ai/UCI Heart Disease
Data.csv")
df = df.loc[:, ~df.columns.str.contains('^Unnamed')]
df = df.fillna(df.median(numeric_only=True))
df['num'] = df['num'].apply(lambda x: 1 if x>0 else 0)

X = df.drop(['id','num'], axis=1)
X = pd.get_dummies(X, drop_first=True)   # <-
y = df['num']

X_train, X_test, y_train, y_test = train_test_split(
    X, y, test_size=0.2, random_state=42, stratify=y
)

scaler = StandardScaler()
X_train = scaler.fit_transform(X_train)
X_test = scaler.transform(X_test)

models = {
    "Logistic Regression": LogisticRegression(max_iter=500),
    "SVM": SVC(),
    "KNN": KNeighborsClassifier(),
    "Random Forest": RandomForestClassifier(),
    "Decision Tree": DecisionTreeClassifier()
}

for name, model in models.items():
    model.fit(X_train, y_train)
    pred = model.predict(X_test)
    acc = accuracy_score(y_test, pred)
    print(f"{name} Accuracy: {acc:.4f}")
```

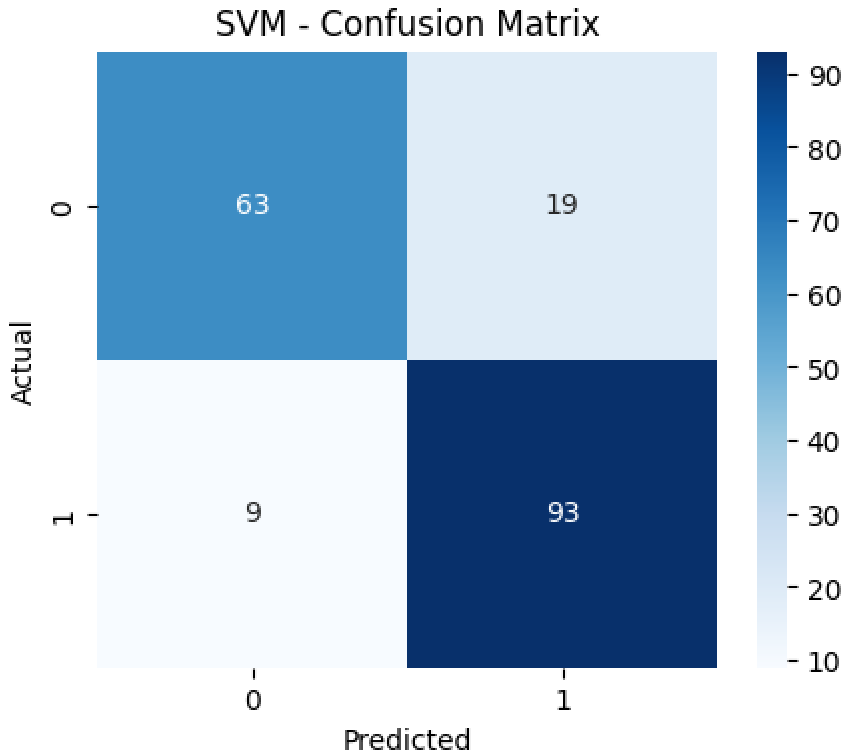
```
Logistic Regression Accuracy: 0.8207
SVM Accuracy: 0.8478
KNN Accuracy: 0.8478
Random Forest Accuracy: 0.8424
Decision Tree Accuracy: 0.7880
```

In [ ]:
```
from sklearn.metrics import confusion_matrix, classification_report,
accuracy_score
import seaborn as sns
import matplotlib.pyplot as plt

def evaluate_model(model, X_test, y_test, model_name):
    y_pred = model.predict(X_test)

    print(f"\n============================")
    print(f"Model: {model_name}")
    print("============================")

    print("Accuracy:", accuracy_score(y_test, y_pred))

    print("\nClassification Report:")
    print(classification_report(y_test, y_pred))

    cm = confusion_matrix(y_test, y_pred)
    plt.figure(figsize=(5,4))
    sns.heatmap(cm, annot=True, cmap="Blues", fmt="d")
    plt.title(f"{model_name} - Confusion Matrix")
    plt.xlabel("Predicted")
    plt.ylabel("Actual")
    plt.show()

# RUN EVALUATION FOR ALL 5 MODELS
for name, model in models.items():
    evaluate_model(model, X_test, y_test, name)
```

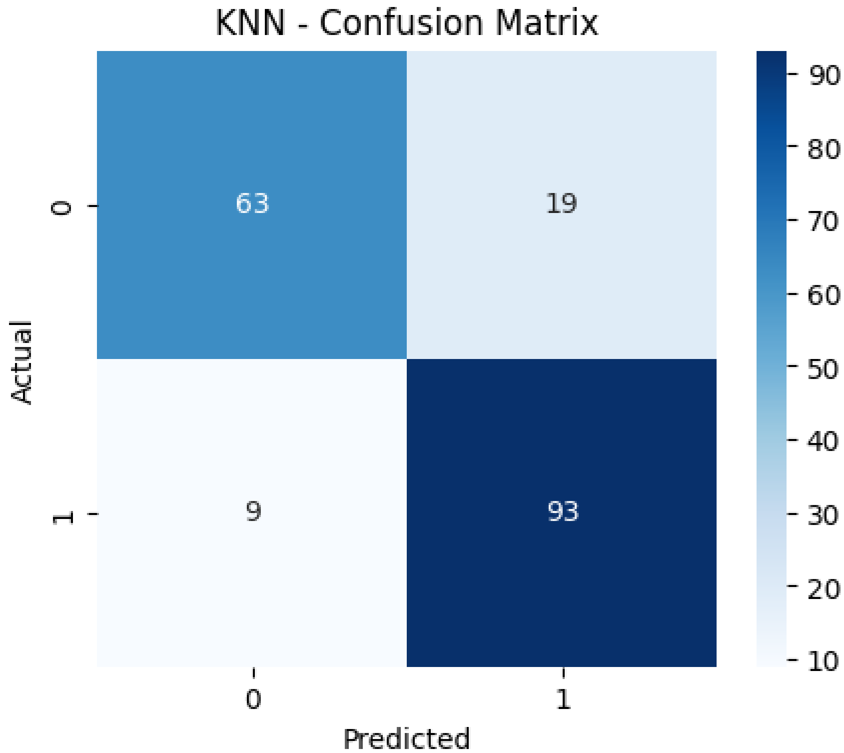
```
============================
Model: Logistic Regression
============================
Accuracy: 0.8206521739130435

Classification Report:
              precision    recall  f1-score   support

           0       0.84      0.74      0.79        82
           1       0.81      0.88      0.85       102

    accuracy                           0.82       184
   macro avg       0.82      0.81      0.82       184
weighted avg       0.82      0.82      0.82       184
```



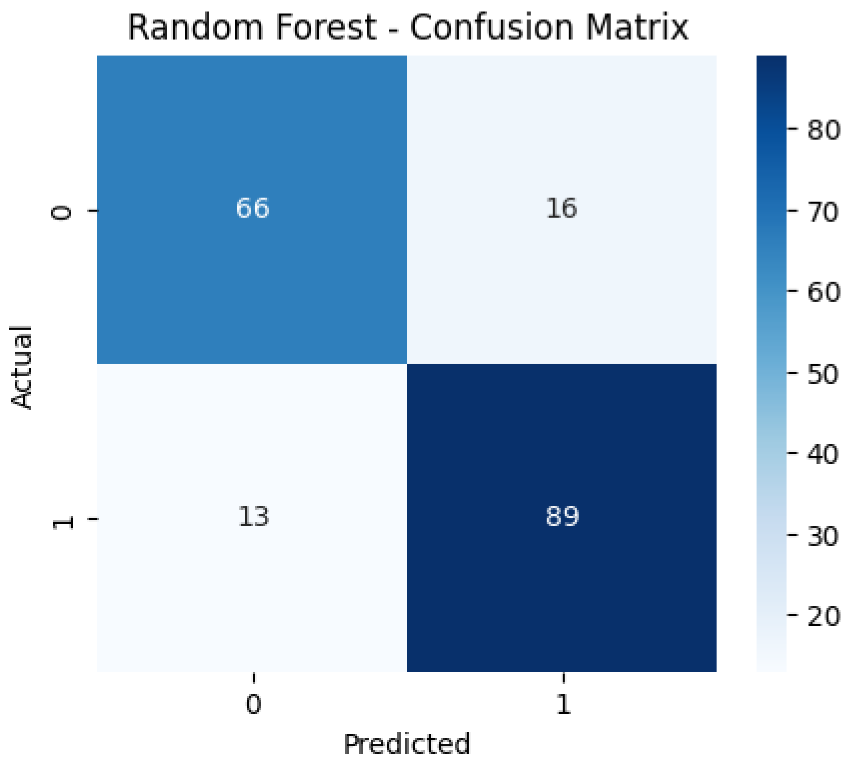

```
============================
Model: SVM
============================
Accuracy: 0.8478260869565217

Classification Report:
              precision    recall  f1-score   support

           0       0.88      0.77      0.82        82
           1       0.83      0.91      0.87       102

    accuracy                           0.85       184
   macro avg       0.85      0.84      0.84       184
weighted avg       0.85      0.85      0.85       184
```



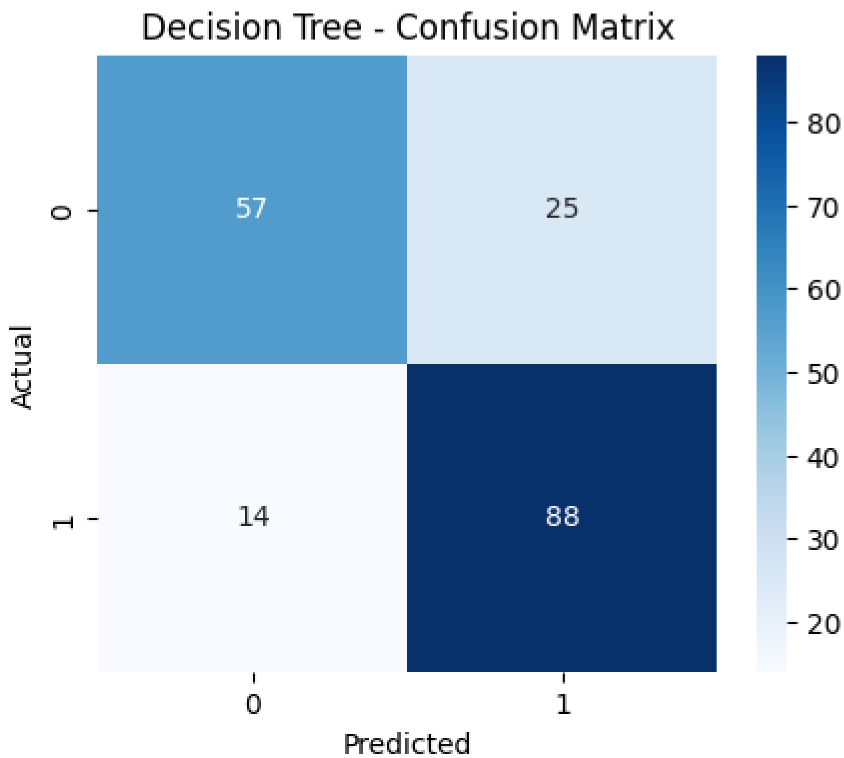

```
============================
Model: KNN
============================
Accuracy: 0.8478260869565217

Classification Report:
              precision    recall  f1-score   support

           0       0.88      0.77      0.82        82
           1       0.83      0.91      0.87       102

    accuracy                           0.85       184
   macro avg       0.85      0.84      0.84       184
weighted avg       0.85      0.85      0.85       184
```



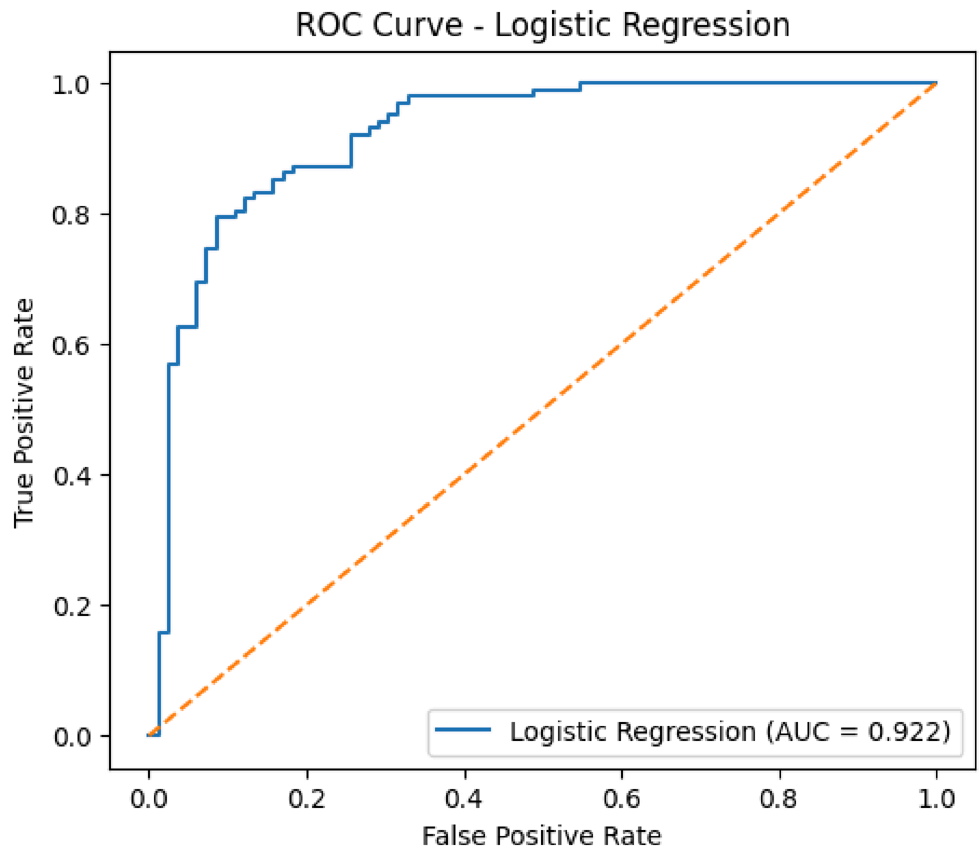

```
============================
Model: Random Forest
============================
Accuracy: 0.842391304347826

Classification Report:
              precision    recall  f1-score   support

           0       0.84      0.80      0.82        82
           1       0.85      0.87      0.86       102

    accuracy                           0.84       184
   macro avg       0.84      0.84      0.84       184
weighted avg       0.84      0.84      0.84       184
```

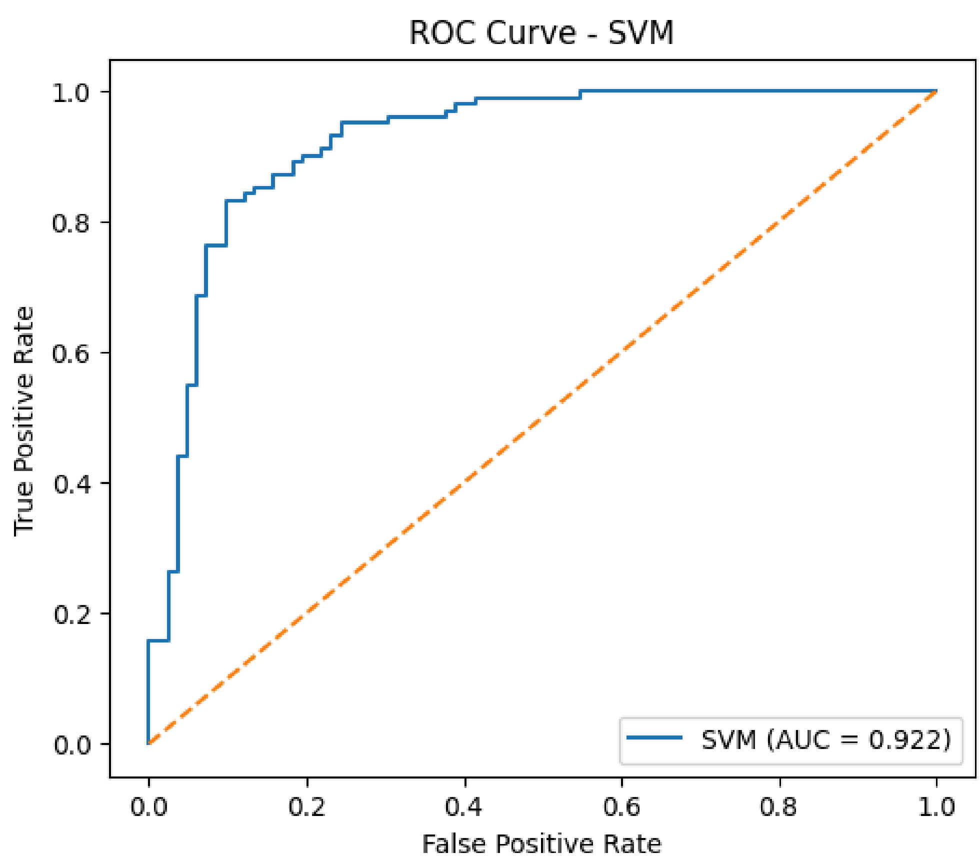


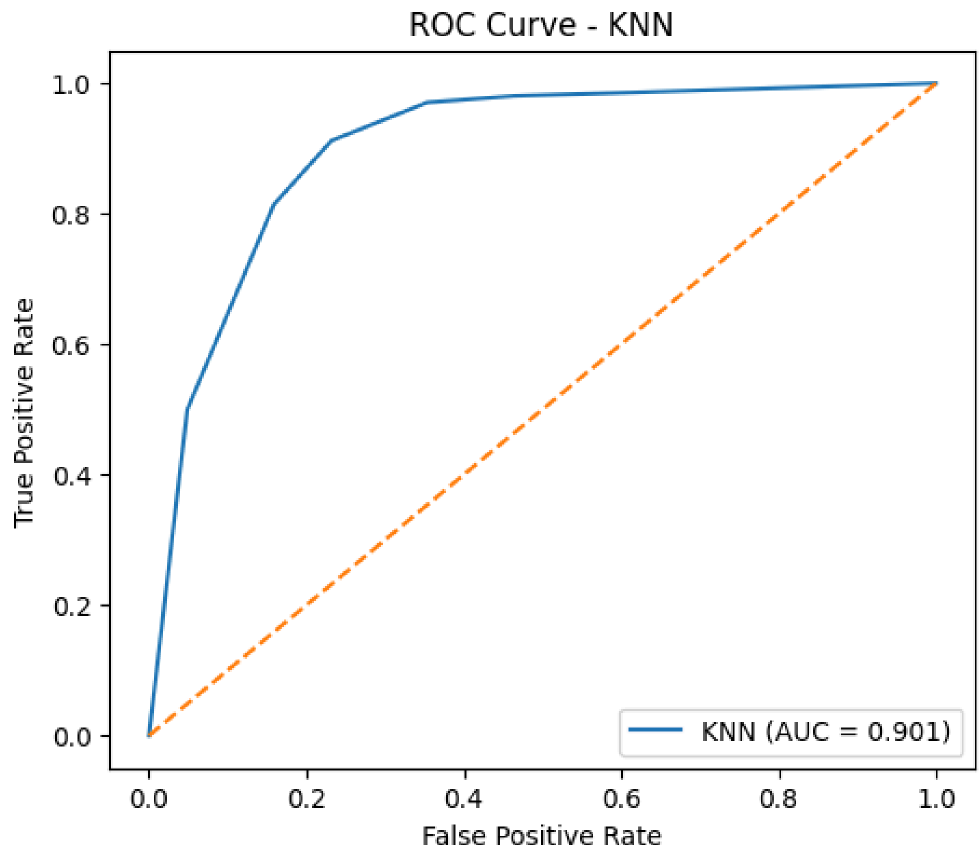

```
============================
Model: Decision Tree
============================
Accuracy: 0.7880434782608695

Classification Report:
              precision    recall  f1-score   support

           0       0.80      0.70      0.75        82
           1       0.78      0.86      0.82       102

    accuracy                           0.79       184
   macro avg       0.79      0.78      0.78       184
weighted avg       0.79      0.79      0.79       184
```

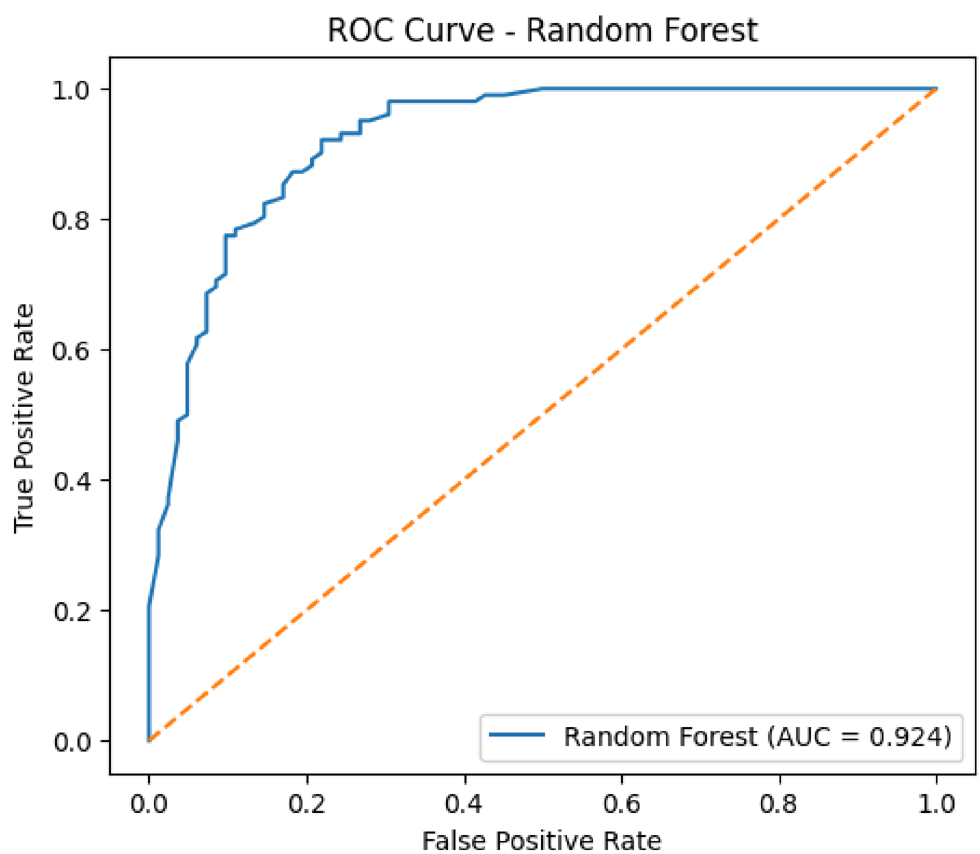

Decision Tree - Confusion Matrix
Actual
Predicted
0
1
0
1
57
25
14
88
80
70
60
50
40
30
20

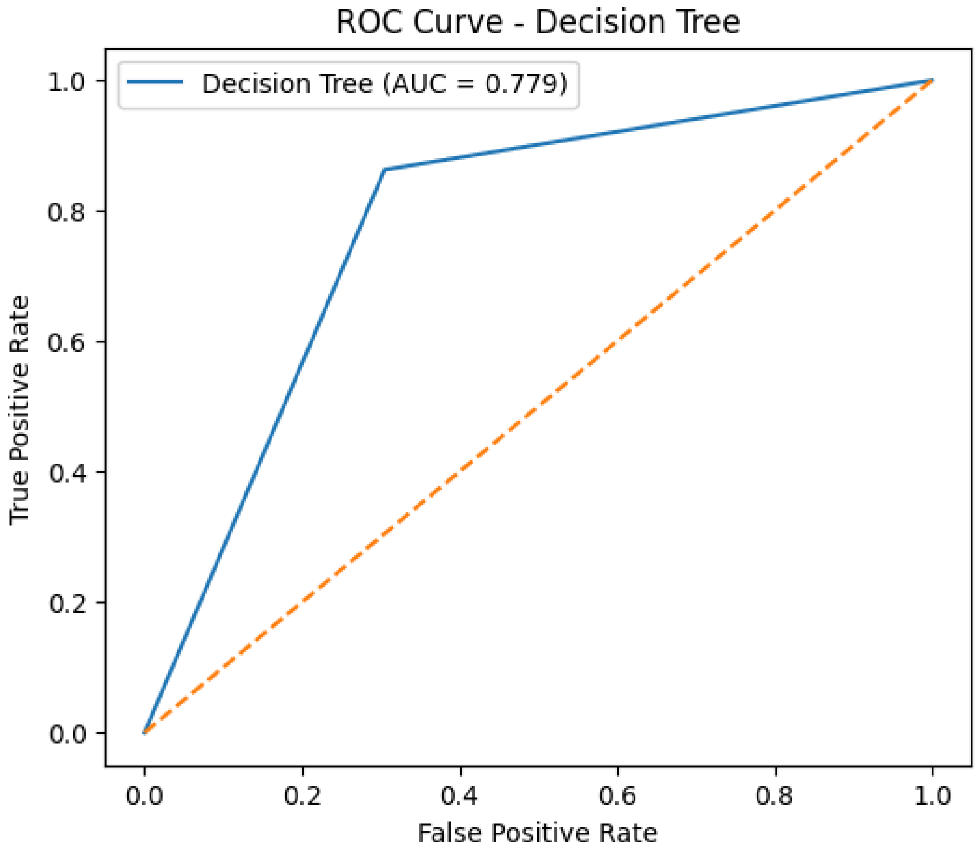
In [ ]:
```
from sklearn.metrics import roc_curve, auc
import matplotlib.pyplot as plt

def plot_roc_curve(model, X_test, y_test, model_name):
    if hasattr(model, "predict_proba"):
        y_prob = model.predict_proba(X_test)[:, 1]
    elif hasattr(model, "decision_function"):
        y_prob = model.decision_function(X_test)
    else:
        print(f"{model_name} does not support ROC curve.")
        return

    fpr, tpr, _ = roc_curve(y_test, y_prob)
    roc_auc = auc(fpr, tpr)

    plt.figure(figsize=(6, 5))
    plt.plot(fpr, tpr, label=f"{model_name} (AUC = {roc_auc:.3f})")
    plt.plot([0, 1], [0, 1], linestyle="--")
    plt.xlabel("False Positive Rate")
    plt.ylabel("True Positive Rate")
    plt.title(f"ROC Curve - {model_name}")
    plt.legend()
    plt.show()


# RUN ROC FOR ALL MODELS
for name, model in models.items():
    plot_roc_curve(model, X_test, y_test, name)
```


ROC Curve - Logistic Regression
True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
Logistic Regression (AUC = 0.922)


ROC Curve - SVM
True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
SVM (AUC = 0.922)

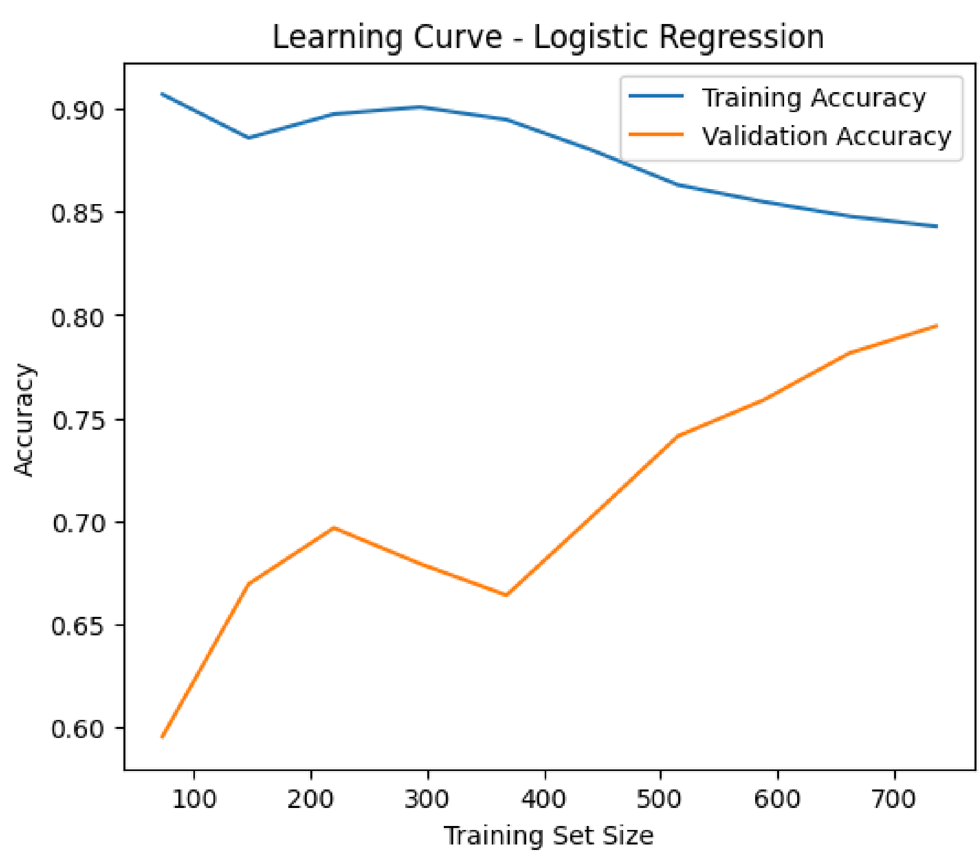

ROC Curve - KNN
True Positive Rate
False Positive Rate
KNN (AUC = 0.901)
0.0
0.2
0.4
0.6
0.8
1.0

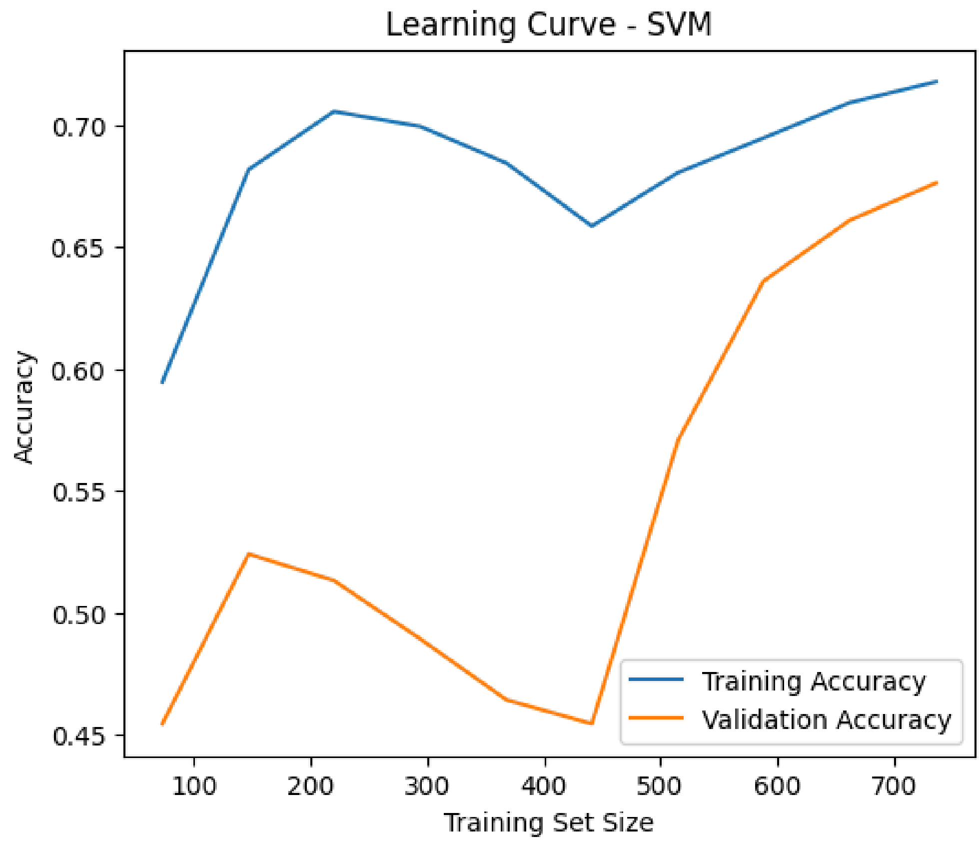

ROC Curve - Random Forest
True Positive Rate
False Positive Rate
Random Forest (AUC = 0.924)
0.0
0.2
0.4
0.6
0.8
1.0

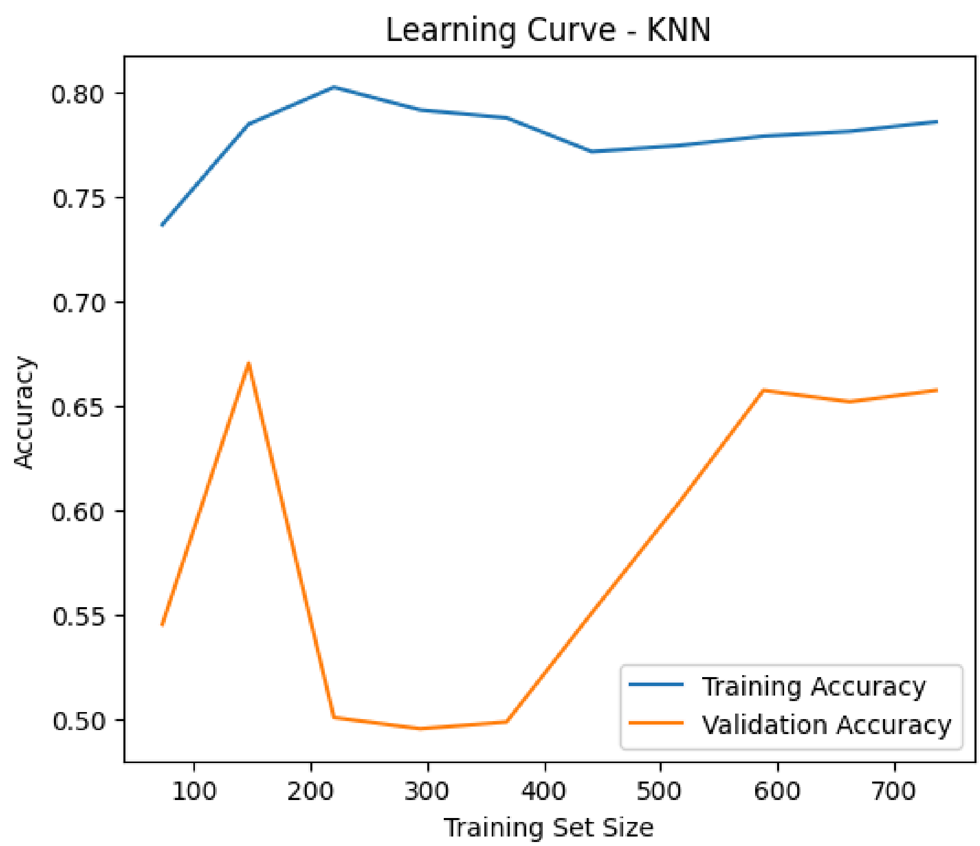

ROC Curve - Decision Tree
Decision Tree (AUC = 0.779)
True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0

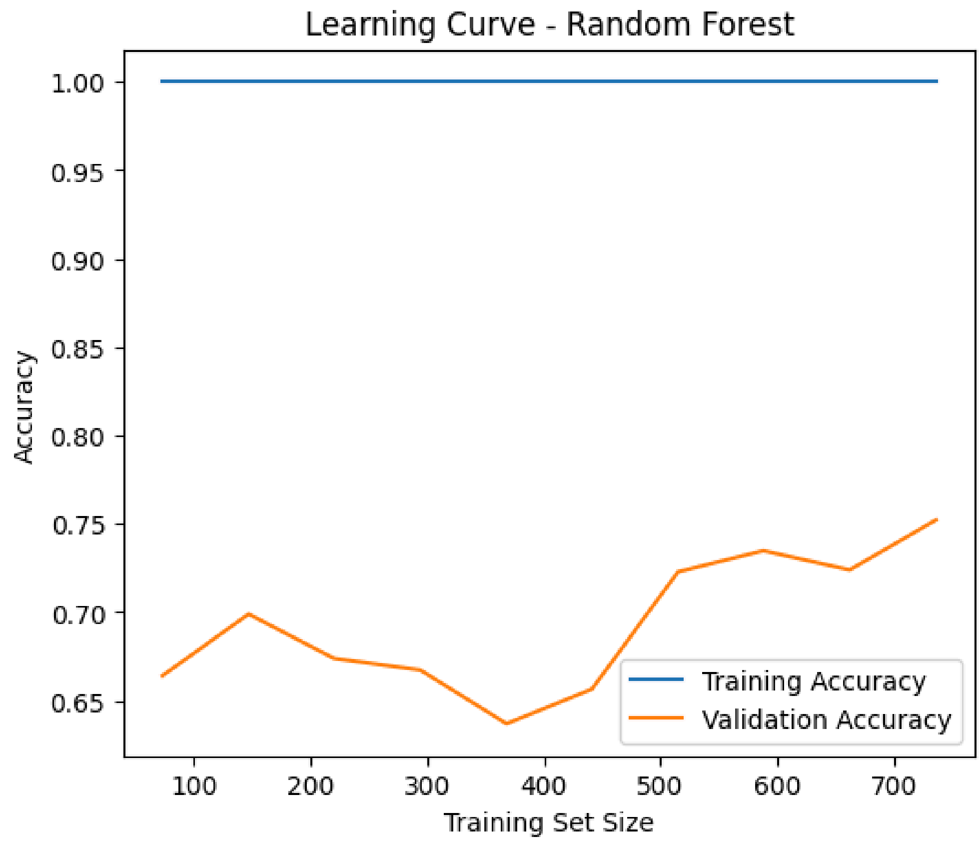
In [ ]:

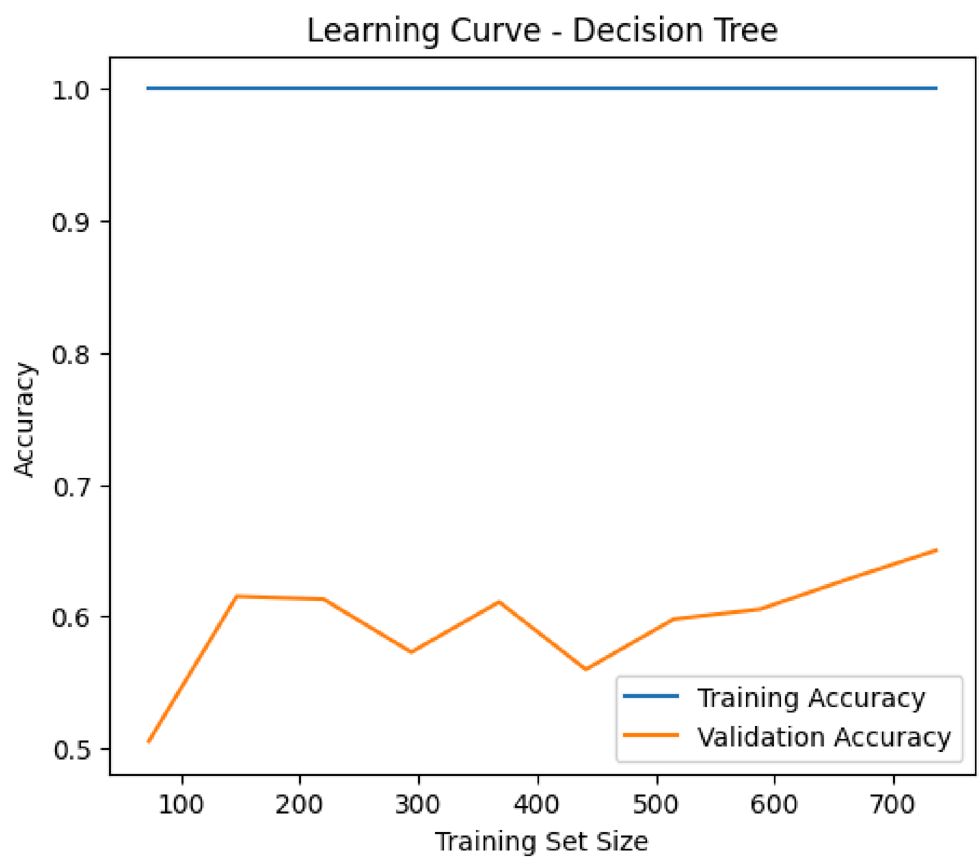
```
from sklearn.model_selection import learning_curve
import numpy as np
import matplotlib.pyplot as plt

def plot_learning_curve(model, X, y, model_name):
    train_sizes, train_scores, test_scores = learning_curve(
        model, X, y,
        cv=5,
        scoring='accuracy',
        train_sizes=np.linspace(0.1, 1.0, 10),
        n_jobs=-1
    )

    train_mean = np.mean(train_scores, axis=1)
    test_mean = np.mean(test_scores, axis=1)

    plt.figure(figsize=(6,5))
    plt.plot(train_sizes, train_mean, label="Training Accuracy")
    plt.plot(train_sizes, test_mean, label="Validation Accuracy")
    plt.title(f"Learning Curve - {model_name}")
    plt.xlabel("Training Set Size")
    plt.ylabel("Accuracy")
    plt.legend()
    plt.show()

# RUN LEARNING CURVES FOR ALL MODELS
for name, model in models.items():
    plot_learning_curve(model, X, y, name)
```




Learning Curve - SVM
Accuracy
Training Set Size
0.70
0.65
0.60
0.55
0.50
0.45
100
200
300
400
500
600
700
Training Accuracy
Validation Accuracy


Learning Curve - KNN
Accuracy
Training Set Size
0.80
0.75
0.70
0.65
0.60
0.55
0.50
100
200
300
400
500
600
700
Training Accuracy
Validation Accuracy


Learning Curve - Random Forest
Accuracy
Training Set Size
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
100
200
300
400
500
600
700
Training Accuracy
Validation Accuracy


Learning Curve - Decision Tree
Accuracy
Training Set Size
1.0
0.9
0.8
0.7
0.6
0.5
100
200
300
400
500
600
700
Training Accuracy
Validation Accuracy