0.) Import and Clean data

```
import pandas as pd
from google.colab import drive
import matplotlib.pyplot as plt
import numpy as np


from sklearn.linear_model import LogisticRegression
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import BaggingClassifier
from sklearn.datasets import make_classification
from sklearn.metrics import accuracy_score
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
from sklearn.tree import plot_tree
from sklearn.metrics import confusion_matrix
import seaborn as sns


drive.mount('/content/gdrive/', force_remount = True)
```

```
Mounted at /content/gdrive/
```

```
df = pd.read_csv("/content/gdrive/MyDrive/Econ441B/bank-additional-full.csv", sep = ";")


df.head()
```

	age	job	marital	education	default	housing	loan	contact	month	day_of_week
0	56	housemaid	married	basic.4y	no	no	no	telephone	may	mon
1	57	services	married	high.school	unknown	no	no	telephone	may	mon
2	37	services	married	high.school	no	yes	no	telephone	may	mon
3	40	admin.	married	basic.6y	no	no	no	telephone	may	mon
4	56	services	married	high.school	no	no	yes	telephone	may	mon

5 rows × 21 columns

```
df = df.drop(["default", "pdays",   "previous", "poutcome", "emp.var.rate", "cons.price.idx",   "cons.conf.idx",    "euribor3m",    "nr.emplo
df = pd.get_dummies(df, columns = ["loan", "job","marital","housing","contact","day_of_week", "campaign", "month", "education"],drop_first =


df.head()
```

	age	duration	y	loan_unknown	loan_yes	job_blue-collar	job_entrepreneur	job_housemaid	job
0	56	261	no	0	0	0	0	1	
1	57	149	no	0	0	0	0	0	
2	37	226	no	0	0	0	0	0	
3	40	151	no	0	0	0	0	0	
4	56	307	no	0	1	0	0	0	

5 rows × 83 columns

```
y = pd.get_dummies(df["y"], drop_first = True)
X = df.drop(["y"], axis = 1)


X
```

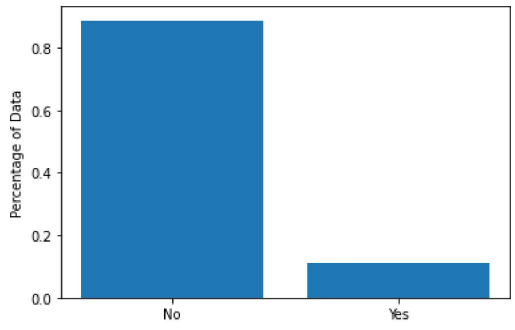
	age	duration	loan_unknown	loan_yes	job_blue-collar	job_entrepreneur	job_housemaid	job
0	56	261	0	0	0	0	1	
1	57	149	0	0	0	0	0	
2	37	226	0	0	0	0	0	
3	40	151	0	0	0	0	0	
4	56	307	0	1	0	0	0	
...	...	...	...	...	...	...	...	
41183	73	334	0	0	0	0	0	
41184	46	383	0	0	1	0	0	
41185	56	189	0	0	0	0	0	
41186	44	442	0	0	0	0	0	

y

	yes
0	0
1	0
2	0
3	0
4	0
...	...
41183	1
41184	0
41185	0
41186	1
41187	0

41188 rows × 1 columns

```
obs = len(y)
plt.bar(["No","Yes"],[len(y[y.yes==0])/obs,len(y[y.yes==1])/obs])
plt.ylabel("Percentage of Data")
plt.show()
```




```
# Train Test Split
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state=42)

scaler = StandardScaler().fit(X_train)

X_scaled = scaler.transform(X_train)
X_test = scaler.transform(X_test)
```

1.) Based on the visualization above, use your expert opinion to transform the data based on what we learned this quarter

- As we can see from the visualization above, around 85% of our data is "no" and around 15% is "yes." Due to this discrepancy, I will apply RandomOverSampler in order to make more samples for the minority class, 'yes', until it has the same amount of samples as 'no', the majority class.

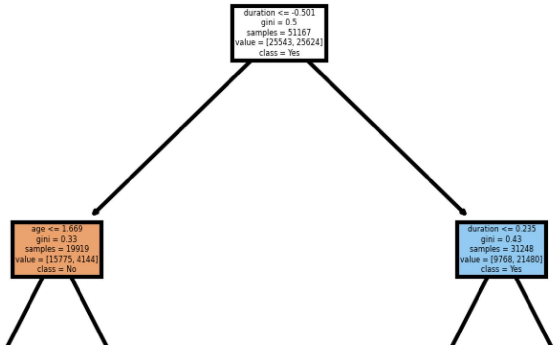
```
###############
###TRANSFORM###
###############

from imblearn.over_sampling import RandomOverSampler
# Resample the data
ros = RandomOverSampler(random_state=42)
X, y = ros.fit_resample(X, y)

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state=42)
scaler = StandardScaler().fit(X_train)
X_scaled = scaler.transform(X_train)
X_test = scaler.transform(X_test)
```

2.) Build and visualize a decision tree of Max Depth 3. Show the confusion matrix.

```
dtree = DecisionTreeClassifier(max_depth = 3)
dtree.fit(X_scaled, y_train)
```

```
DecisionTreeClassifier
DecisionTreeClassifier(max_depth=3)
```

```
fig, axes = plt.subplots(nrows = 1,ncols = 1,figsize = (4,4), dpi=300)
plot_tree(dtree, filled = True, feature_names = X.columns, class_names=["No","Yes"])
fig.savefig('tree2.png')
```



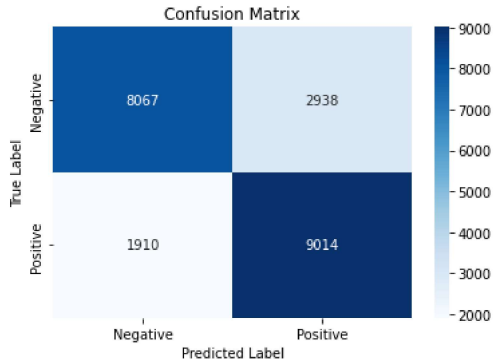
2b.) Confusion matrix on out of sample data. Visualize and store as variable

```
y_pred = dtree.predict(X_test)
y_true = y_test
cm_raw = confusion_matrix(y_true, y_pred)
```

```
y_pred
```

```
array([0, 0, 0, ..., 0, 1, 0], dtype=uint8)
```

```
tree_predictions = y_pred.copy()


class_labels = ['Negative', 'Positive']

sns.heatmap(cm_raw, annot=True, fmt='d', cmap='Blues', xticklabels=class_labels, yticklabels=class_labels)
plt.title('Confusion Matrix')
plt.xlabel('Predicted Label')
plt.ylabel('True Label')
plt.show()

plt.savefig('oos_conf_matrix.png')
# will get a conf based on out of sample data
```




```
<Figure size 432x288 with 0 Axes>
```

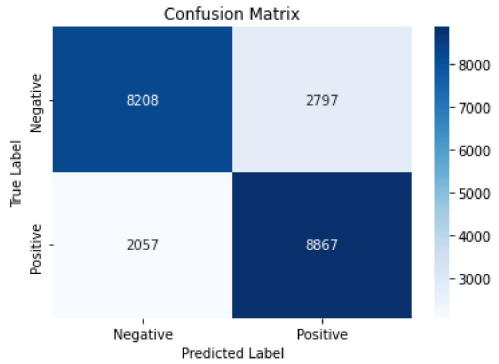
3.) Use bagging on your descision tree

```
dtree = DecisionTreeClassifier(max_depth = 3)

bagging = BaggingClassifier(estimator=dtree,
                            n_estimators=100,
                            max_samples=0.5,
                            max_features=1.)

bagging.fit(X_scaled, y_train)
```

```
y_pred = bagging.predict(X_test)

accuracy = accuracy_score(y_test, y_pred)
print("Accuracy:", accuracy)
```

```
/usr/local/lib/python3.8/dist-packages/sklearn/ensemble/_bagging.py:802: DataConversionWarning: A column-vector y was passed when a 1d a
  y = column_or_1d(y, warn=True)
Accuracy: 0.7786492772128232
```

```
bagging_predictions = y_pred.copy()


y_true = y_test
cm_bag = confusion_matrix(y_true, y_pred)


class_labels = ['Negative', 'Positive']

sns.heatmap(cm_bag, annot=True, fmt='d', cmap='Blues', xticklabels=class_labels, yticklabels=class_labels)
plt.title('Confusion Matrix')
plt.xlabel('Predicted Label')
plt.ylabel('True Label')
plt.show()
```




```
plt.savefig('second_conf_matrix.png')
```

```
<Figure size 432x288 with 0 Axes>
```

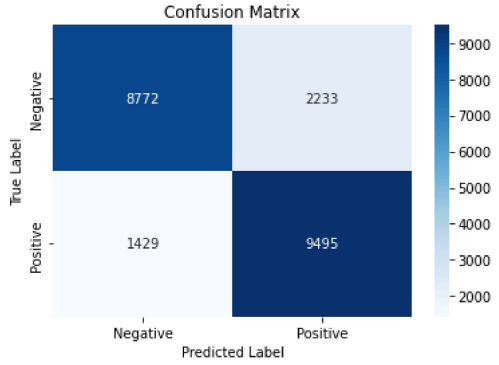
4.) Boost your tree

```
from sklearn.ensemble import AdaBoostClassifier


dtree = DecisionTreeClassifier(max_depth=3)
adaboost = AdaBoostClassifier(base_estimator=dtree, n_estimators=50, learning_rate=0.1)

adaboost.fit(X_scaled, y_train)

y_pred = adaboost.predict(X_test)
```

```
/usr/local/lib/python3.8/dist-packages/sklearn/utils/validation.py:1143: DataConversionWarning: A column-vector y was passed when a 1d a
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.8/dist-packages/sklearn/ensemble/_base.py:166: FutureWarning: `base_estimator` was renamed to `estimator` in vers
  warnings.warn(
```

```
boosting_predictions = y_pred.copy()


y_true = y_test
cm_boost = confusion_matrix(y_true, y_pred)
```

```
class_labels = ['Negative', 'Positive']

sns.heatmap(cm_boost, annot=True, fmt='d', cmap='Blues', xticklabels=class_labels, yticklabels=class_labels)
plt.title('Confusion Matrix')
plt.xlabel('Predicted Label')
plt.ylabel('True Label')
plt.show()
```




```
plt.savefig('third_conf_matrix.png')
```

```
<Figure size 432x288 with 0 Axes>
```

5.) Create a superlearner with at least 5 base learner models. Use a logistic reg for your metalearner. Interpret your coefficients and save your CM.

```
pip install mlens
```

```
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/
Requirement already satisfied: mlens in /usr/local/lib/python3.8/dist-packages (0.2.3)
Requirement already satisfied: numpy>=1.11 in /usr/local/lib/python3.8/dist-packages (from mlens) (1.22.4)
Requirement already satisfied: scipy>=0.17 in /usr/local/lib/python3.8/dist-packages (from mlens) (1.10.1)
```

```
from sklearn.linear_model import LogisticRegression
from sklearn.ensemble import RandomForestClassifier
####IMPORT MORE BASE LEARNERS####
from mlens.ensemble import SuperLearner
from sklearn.neural_network import MLPClassifier
from sklearn.neighbors import KNeighborsClassifier
from xgboost import XGBClassifier


# set base learners
base_learners = [XGBClassifier(),
                 BaggingClassifier(n_estimators=50),
                 RandomForestClassifier(n_estimators=50),
                 MLPClassifier(hidden_layer_sizes=(10, 5)),
                 KNeighborsClassifier(n_neighbors=5)]


super_learner = SuperLearner()


super_learner.add(base_learners)
```

```
SuperLearner(array_check=None, backend=None, folds=2,
       layers=[Layer(backend='threading', dtype=<class 'numpy.float32'>, n_jobs=-1,
   name='layer-1', propagate_features=None, raise_on_exception=True,
   random_state=None, shuffle=False,
   stack=[Group(backend='threading', dtype=<class 'numpy.float32'>,
   indexer=FoldIndex(X=None, folds=2, raise_on_ex...rer=None)],
   n_jobs=-1, name='group-3', raise_on_exception=True, transformers=[])],
   verbose=0)],
       model_selection=False, n_jobs=None, raise_on_exception=True,
       random_state=None, sample_size=20, scorer=None, shuffle=False,
       verbose=False)
```

```
# fit to training data
```

```
super_learner.fit(X_scaled, y_train)
```

```
/usr/local/lib/python3.8/dist-packages/sklearn/ensemble/_bagging.py:802: DataConversionWarning: A column-vector y was passed when a 1d a
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.8/dist-packages/sklearn/ensemble/_bagging.py:802: DataConversionWarning: A column-vector y was passed when a 1d a
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.8/dist-packages/sklearn/ensemble/_bagging.py:802: DataConversionWarning: A column-vector y was passed when a 1d a
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.8/dist-packages/sklearn/neighbors/_classification.py:215: DataConversionWarning: A column-vector y was passed whe
  return self._fit(X, y)
/usr/local/lib/python3.8/dist-packages/sklearn/neighbors/_classification.py:215: DataConversionWarning: A column-vector y was passed whe
  return self._fit(X, y)
/usr/local/lib/python3.8/dist-packages/sklearn/neighbors/_classification.py:215: DataConversionWarning: A column-vector y was passed whe
  return self._fit(X, y)
/usr/local/lib/python3.8/dist-packages/sklearn/neural_network/_multilayer_perceptron.py:1096: DataConversionWarning: A column-vector y w
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.8/dist-packages/sklearn/neural_network/_multilayer_perceptron.py:1096: DataConversionWarning: A column-vector y w
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.8/dist-packages/sklearn/neural_network/_multilayer_perceptron.py:684: ConvergenceWarning: Stochastic Optimizer: M
  warnings.warn(
/usr/local/lib/python3.8/dist-packages/sklearn/neural_network/_multilayer_perceptron.py:1096: DataConversionWarning: A column-vector y w
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.8/dist-packages/mlens/parallel/learner.py:179: DataConversionWarning: A column-vector y was passed when a 1d arra
  self.estimator.fit(xtemp, ytemp)
/usr/local/lib/python3.8/dist-packages/mlens/parallel/learner.py:179: DataConversionWarning: A column-vector y was passed when a 1d arra
  self.estimator.fit(xtemp, ytemp)
/usr/local/lib/python3.8/dist-packages/mlens/parallel/learner.py:179: DataConversionWarning: A column-vector y was passed when a 1d arra
  self.estimator.fit(xtemp, ytemp)
SuperLearner(array_check=None, backend=None, folds=2,
       layers=[Layer(backend='threading', dtype=<class 'numpy.float32'>, n_jobs=-1,
   name='layer-1', propagate_features=None, raise_on_exception=True,
   random_state=None, shuffle=False,
   stack=[Group(backend='threading', dtype=<class 'numpy.float32'>,
   indexer=FoldIndex(X=None, folds=2, raise_on_ex...rer=None)],
   n_jobs=-1, name='group-3', raise_on_exception=True, transformers=[])],
   verbose=0)],
       model_selection=False, n_jobs=None, raise_on_exception=True,
       random_state=None, sample_size=20, scorer=None, shuffle=False,
       verbose=False)
```

```
# get base predictions
base_predictions= super_learner.predict(X_train)
# base_predictions= super_learner.predict(X_scaled) I think this is right but he had the above in his code so I will go with that
```

```
/usr/local/lib/python3.8/dist-packages/sklearn/base.py:413: UserWarning: X has feature names, but BaggingClassifier was fitted without f
  warnings.warn(
/usr/local/lib/python3.8/dist-packages/sklearn/base.py:413: UserWarning: X has feature names, but KNeighborsClassifier was fitted withou
  warnings.warn(
/usr/local/lib/python3.8/dist-packages/sklearn/base.py:413: UserWarning: X has feature names, but MLPClassifier was fitted without featu
  warnings.warn(
/usr/local/lib/python3.8/dist-packages/sklearn/base.py:413: UserWarning: X has feature names, but RandomForestClassifier was fitted with
  warnings.warn(
```

```
base_predictions
```

```
array([[0., 1., 1., 1., 1.],
       [0., 1., 1., 1., 0.],
       [0., 1., 1., 1., 1.],
       ...,
       [0., 1., 1., 1., 1.],
       [0., 1., 1., 1., 1.],
       [0., 1., 1., 1., 1.]], dtype=float32)
```

```
# train meta learner
log_reg = LogisticRegression().fit(base_predictions, y_train) # he had base_learners here but it says it wants a higher d array
```

```
/usr/local/lib/python3.8/dist-packages/sklearn/utils/validation.py:1143: DataConversionWarning: A column-vector y was passed when a 1d a
  y = column_or_1d(y, warn=True)
```

```
# Interpret Coefficients
log_reg.coef_
```

```
array([[-0.03835268, -0.1598248 , -0.1598248 ,  0.35987468,  0.15003727]])
```

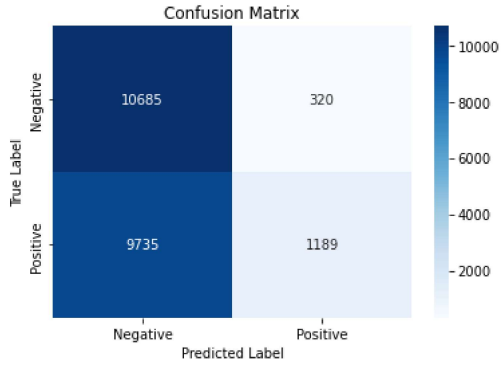
Above, you can see that we get the following coefficients. From these coefficients, we can learn the importance of the models we looked at in base_learners. We can see that we received a negative coefficient for the XGB Classifier, Bagging Classifier, and Random Forest Classifier with the XGB classifier coefficient being the smallest. With the MLP Classifier and KNeighbors Classifier we received positive coefficients with the MLP Classifier's coefficient being the largest. From this we can determine that the XGB Classifier had the biggest negative effect on our model, while the MLP Classifier had the largest positive effect.

```
# get predictions on test set
base_predictions_test = super_learner.predict(X_test)
log_reg_predictions = log_reg.predict(base_predictions_test)
```

```
from sklearn.metrics import confusion_matrix

# create confusion matrix
conf_mat = confusion_matrix(y_test, log_reg_predictions)

print(conf_mat)
```

```
[[10685   320]
 [ 9735  1189]]
```

```
class_labels = ['Negative', 'Positive']

sns.heatmap(conf_mat, annot=True, fmt='d', cmap='Blues', xticklabels=class_labels, yticklabels=class_labels)
plt.title('Confusion Matrix')
plt.xlabel('Predicted Label')
plt.ylabel('True Label')
plt.show()
```




```
plt.savefig('fourth_conf_matrix.png')
```

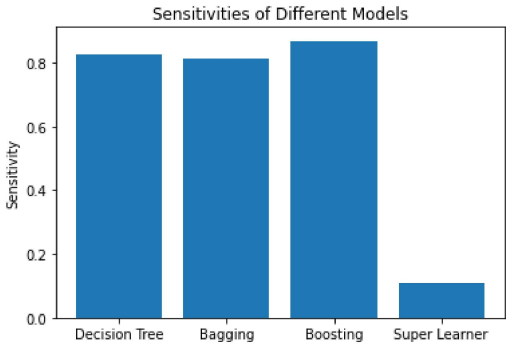
```
<Figure size 432x288 with 0 Axes>
```

6.) Create a bar chart comparing decision tree, bagged, boosted and super learner Sensitivities and specificities (Out of Sample)

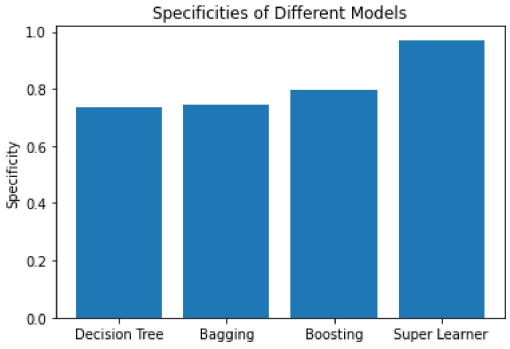
```
from sklearn.metrics import classification_report

# classification report for each model
tree_report = classification_report(y_test, tree_predictions, output_dict=True)
bagging_report = classification_report(y_test, bagging_predictions, output_dict=True)
boosting_report = classification_report(y_test, boosting_predictions, output_dict=True)
superlearner_report = classification_report(y_test, log_reg_predictions, output_dict=True)
```

```
# gets the Sensitivities and Specificities from classification report
tree_sensitivity = tree_report['1']['recall']
bagging_sensitivity = bagging_report['1']['recall']
boosting_sensitivity = boosting_report['1']['recall']
superlearner_sensitivity = superlearner_report['1']['recall']
```

```
tree_specificity = tree_report['0']['recall']
bagging_specificity = bagging_report['0']['recall']
boosting_specificity = boosting_report['0']['recall']
superlearner_specificity = superlearner_report['0']['recall']


sensitivities = [tree_sensitivity, bagging_sensitivity, boosting_sensitivity, superlearner_sensitivity]
specificities = [tree_specificity, bagging_specificity, boosting_specificity, superlearner_specificity]



import matplotlib.pyplot as plt

# create bar chart for Sensitivities
plt.bar(['Decision Tree', 'Bagging', 'Boosting', 'Super Learner'], sensitivities)
plt.title('Sensitivities of Different Models')
plt.ylabel('Sensitivity')
plt.show()
```




```
# create bar chart for Specificities
plt.bar(['Decision Tree', 'Bagging', 'Boosting', 'Super Learner'], specificities)
plt.title('Specificities of Different Models')
plt.ylabel('Specificity')
plt.show()
```




```
#AWS Sagemaker
```