Part 1

In [ ]:
```
import pandas as pd
from sklearn.datasets import fetch_openml
mnist = fetch_openml('mnist_784', version = 1)
mnist.keys()
```

Out[ ]:
```
dict_keys(['data', 'target', 'frame', 'categories', 'feature_names', 'target_names', 'DESCR', 'details', 'url'])
```

In [ ]:
```
X, y = mnist["data"], mnist["target"]
X.shape
```

Out[ ]:
```
(70000, 784)
```

In [ ]:
```
y.shape
```

Out[ ]:
```
(70000,)
```

In [ ]:
```
X.head(2)
```

Out[ ]:

	pixel1	pixel2	pixel3	pixel4	pixel5	pixel6	pixel7	pixel8	pixel9	pixel10	...	pixel775	pixel776	pixel777	pixel778	pixel779	pixel780
0	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0

2 rows × 784 columns

In [ ]:
```
y[0]
```

Out[ ]:
```
'5'
```

In [ ]:
```
X = X.to_numpy()
```

In [ ]:
```
import numpy as np
y = y.astype(np.uint8)
y[0]
```

Out[ ]:
```
5
```

In [ ]:
```
import matplotlib.pyplot as plt

some_digit = X[0]
some_digit_image = some_digit.reshape(28,28)
plt.figure(figsize=(3,3))
plt.imshow(some_digit_image, cmap="binary")
plt.axis("off")
plt.show()
```

In [ ]:
```
X_train_RAW, X_test_RAW, y_train_RAW, y_test_RAW = X[:60000], X[60000:], y[:60000], y[60000:]
```

Get a DataFrame column that contain only the 5s and 3s for training and testing

In [ ]:
```
# Train data
y_train_p1 = y_train_RAW[(y_train_RAW == 3) | (y_train_RAW == 5)]

y_train_p1_3 = y_train_p1 == 3

X_train_p1 = X_train_RAW[(y_train_RAW == 3) | (y_train_RAW == 5)]

# Test data
y_test_p1 = y_test_RAW[(y_test_RAW == 3) | (y_test_RAW == 5)]

y_test_p1_3 = y_test_p1 == 3

X_test_p1 = X_test_RAW[(y_test_RAW == 3) | (y_test_RAW == 5)]
```

In [ ]:
```
from sklearn.linear_model import SGDClassifier
sgd_clf = SGDClassifier(random_state=42)
sgd_clf.fit(X_train_p1, y_train_p1_3)
```

Out[ ]:
```
SGDClassifier
SGDClassifier(random_state=42)
```

In [ ]:
```
sgd_clf.predict([some_digit])
```

Out[ ]:
```
array([False])
```

A) Use cross_val_score() to show the accuracy of prediction under cross validation.

In [ ]:
```
from sklearn.model_selection import cross_val_score
cross_val_score(sgd_clf, X_train_p1, y_train_p1_3, cv = 3 , scoring = "accuracy")
```

Out[ ]:
```
array([0.92962867, 0.95299922, 0.94701299])
```

B) Use cross_val_predict() to generate predictions on the training data.

In [ ]:
```
from sklearn.model_selection import cross_val_predict
y_p1_pred = cross_val_predict(sgd_clf, X_train_p1, y_train_p1_3, cv =3)
y_p1_pred
```

Out[ ]:
```
array([False,  True,  True, ..., False,  True, False])
```

Confusion Matrix

In [ ]:
```
from sklearn.metrics import confusion_matrix
confusion_matrix(y_train_p1_3, y_p1_pred)
```

Out[ ]:
```
array([[4994,  427],
       [ 229, 5902]], dtype=int64)
```

Precision Score

In [ ]:
```
from sklearn.metrics import precision_score, recall_score, f1_score
precision_score(y_train_p1_3, y_p1_pred)
```

Out[ ]:
```
0.9325327855901406
```

Recall Score

In [ ]:
```
recall_score(y_train_p1_3, y_p1_pred)
```

Out[ ]:
```
0.9626488337954656
```

F1 Score

In [ ]:
```
f1_score(y_train_p1_3, y_p1_pred)
```

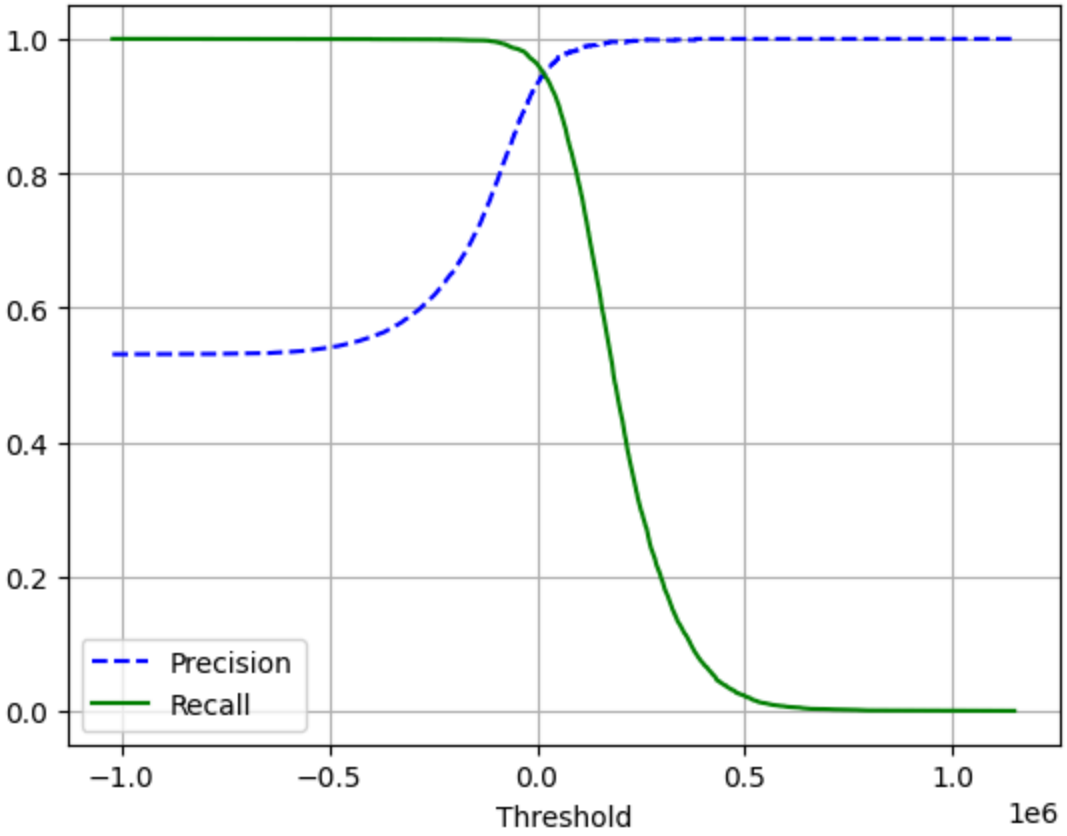
Out[ ]:
```
0.9473515248796147
```

C) Use cross_val_predict() to generate the prediction scores on the training set. Then, plot the precision and recall curves as functions of the threshold value.

In [ ]:
```
from sklearn.metrics import precision_recall_curve

y_scores = cross_val_predict(sgd_clf, X_train_p1, y_train_p1_3, cv = 3, method = "decision_function")
precisions, recalls, thresholds = precision_recall_curve(y_train_p1_3, y_scores)
```

In [ ]:
```
def plot_precision_recall_vs_threshold(precisions, recalls, thresholds):
    plt.plot(thresholds, precisions[:-1], "b--", label = "Precision")
    plt.plot(thresholds, recalls[:-1], "g-", label = "Recall")
    plt.legend(loc = "best")
    plt.grid()
    plt.xlabel('Threshold')
```

In [ ]:
```
plot_precision_recall_vs_threshold(precisions, recalls, thresholds)
plt.show()
```



D) Based on the curves, what will be a sensible threshold value to choose? Generate predictions under the chosen threshold value. Evaluate the precision and recall scores using the predictions.

Because these curves intersect around roughly 0, I will use this as the threshold value to maximize both precision and recall.

In [ ]:
```
threshold_00 = thresholds[np.argmax(precisions >= 0)]
y_p1_pred_00 = (y_scores >= threshold_00)

precision_score(y_train_p1_3, y_p1_pred_00)
```

Out[ ]:
```
0.5307306094182825
```

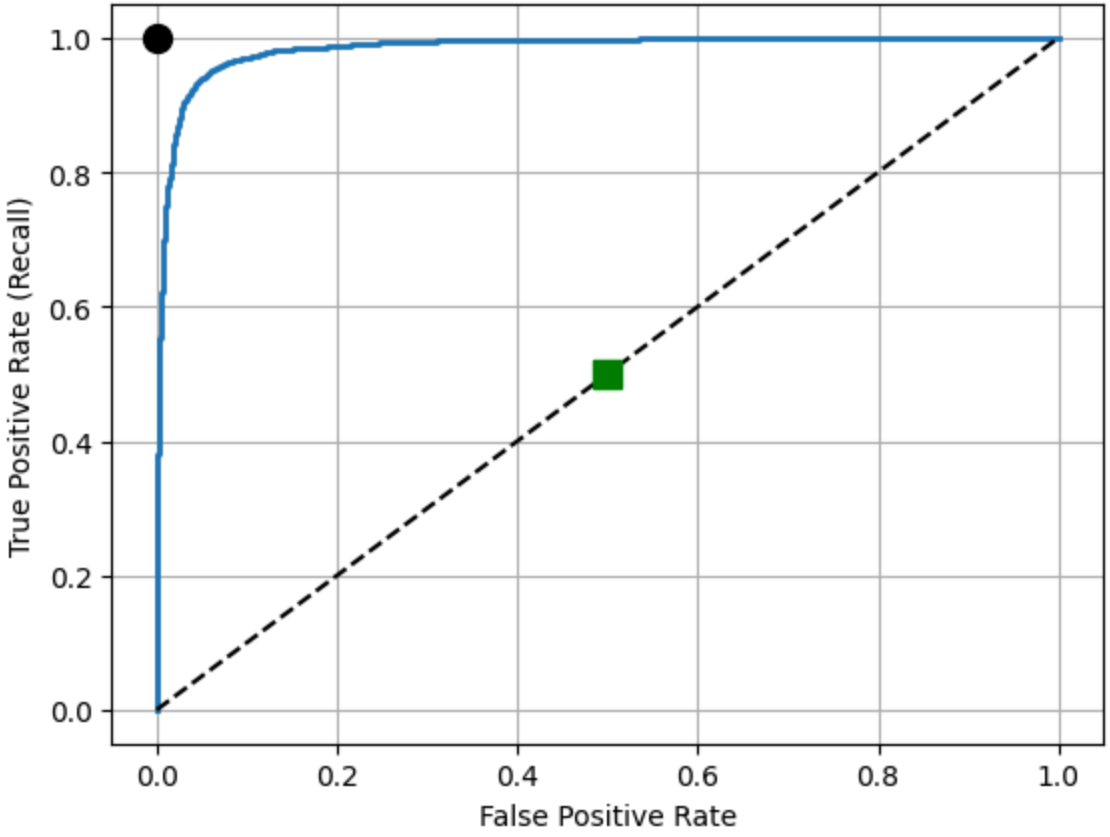
In [ ]:
```
recall_score(y_train_p1_3, y_p1_pred_00)
```

Out[ ]:
```
1.0
```

E) Plot the ROC curve and evaluate the ROC AUC score.

In [ ]:
```
from sklearn.metrics import roc_curve, roc_auc_score

false_positive_rate, true_positive_rate, thresholds = roc_curve(y_train_p1_3, y_scores)
```

In [ ]:
```
def plot_roc_curve(fpr, tpr, label=None):
    plt.plot(fpr, tpr, linewidth=2, label=label)
    plt.plot([0, 1], [0, 1], 'k--')
    plt.grid()
    plt.xlabel('False Positive Rate')
    plt.ylabel('True Positive Rate (Recall)')
    plt.plot(0, 1, marker='o', markersize=10, markeredgecolor="black", markerfacecolor="black")
    plt.plot(0.5, 0.5, marker="s", markersize=10, markeredgecolor="green", markerfacecolor="green")


plot_roc_curve(false_positive_rate, true_positive_rate)
plt.show()
```



ROC AUC Score

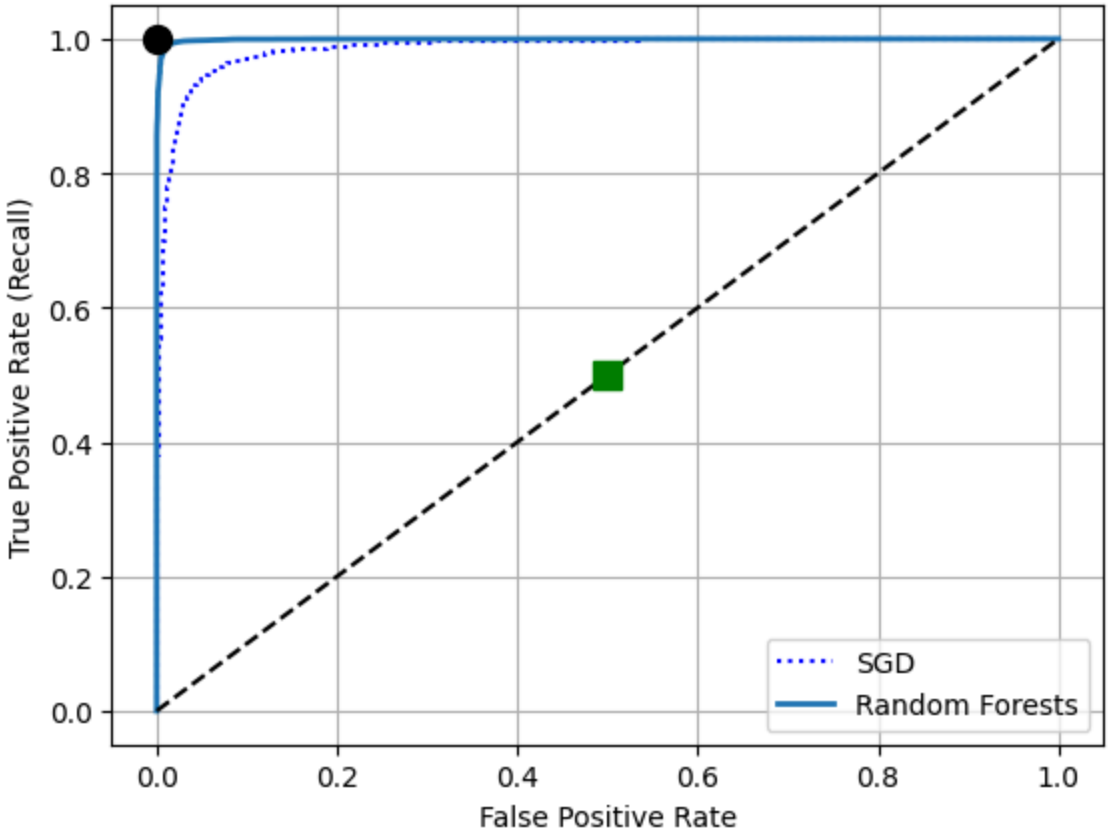
In [ ]:
```
roc_auc_score(y_train_p1_3, y_scores)
```

Out[ ]: 0.9851212013087797

F) RandomForestClassifier

In [ ]:
```
from sklearn.ensemble import RandomForestClassifier
forest_clf = RandomForestClassifier(random_state=42)

y_probas_forest= cross_val_predict(forest_clf, X_train_p1, y_train_p1_3, cv = 3, method = "predict_proba")

y_scores_forest = y_probas_forest[:, 1]
fpr_forest, tpr_forest, thresholds_forest = roc_curve(y_train_p1_3, y_scores_forest)
```

In [ ]:
```
plt.plot(false_positive_rate, true_positive_rate, "b:", label = "SGD")
plot_roc_curve(fpr_forest, tpr_forest, "Random Forests")
plt.legend(loc = "lower right")
plt.show()
```



In [ ]:
```
roc_auc_score(y_train_p1_3, y_scores_forest)
```

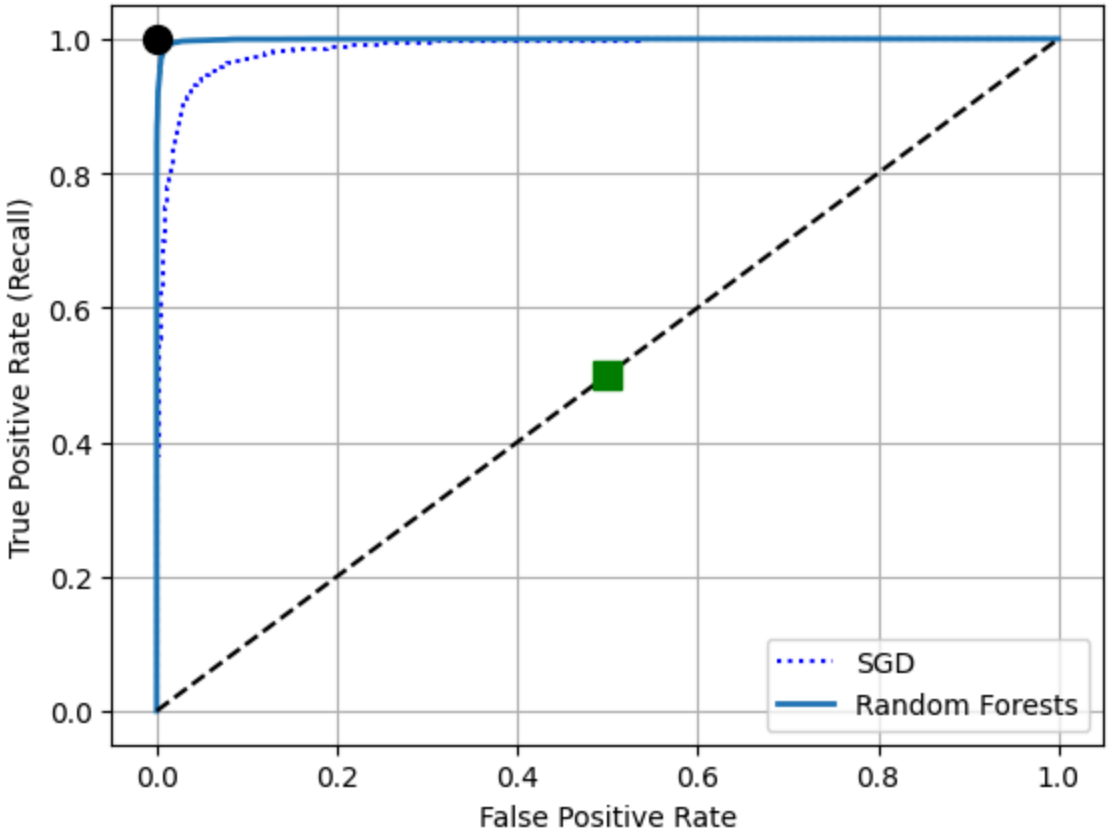
Out[ ]: 0.9992079106873717

G) Standard Scaler on X (features) data before training the model

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

scaler = StandardScaler()
X_train_p1 = scaler.fit_transform(X_train_p1)
```

In [ ]:
```
forest_clf = RandomForestClassifier(random_state=42)


y_probas_forest= cross_val_predict(forest_clf, X_train_p1, y_train_p1_3, cv = 3, method = "predict_proba")

y_scores_forest = y_probas_forest[:, 1]
fpr_forest, tpr_forest, thresholds_forest = roc_curve(y_train_p1_3, y_scores_forest)
```

In [ ]:
```
plt.plot(false_positive_rate, true_positive_rate, "b:", label = "SGD")
plot_roc_curve(fpr_forest, tpr_forest, "Random Forests")
plt.legend(loc = "lower right")
plt.show()
```



In [ ]:
```
roc_auc_score(y_train_p1_3, y_scores_forest)
```

Out[ ]:
```
0.9992048718276675
```