Extra Work

In [1]:
```
import yfinance as yf
import pandas as pd
import matplotlib.pyplot as plt
import numpy as np
from statsmodels.graphics.tsaplots import plot_acf, plot_pacf
from statsmodels.tsa.stattools import adfuller
import statsmodels.api as sm
from sklearn.preprocessing import MinMaxScaler
```

In [2]:
```
from statsmodels.tsa.arima.model import ARIMA
from sklearn.metrics import mean_squared_error
import pmdarima as pm
```

In [3]:
```
from keras.models import Sequential
from keras.layers import Dense, LSTM
from keras.optimizers import Adam
```

In [4]:
```
start_date = '2020-01-01'
end_date = '2023-05-12'

ap = yf.download("AAPL", start_date , end_date)['Close']
```

```
[**********100%%**********]  1 of 1 completed
```

In [5]:
```
ap = pd.DataFrame(ap)
ap[ap.isna().any(axis=1)]
```

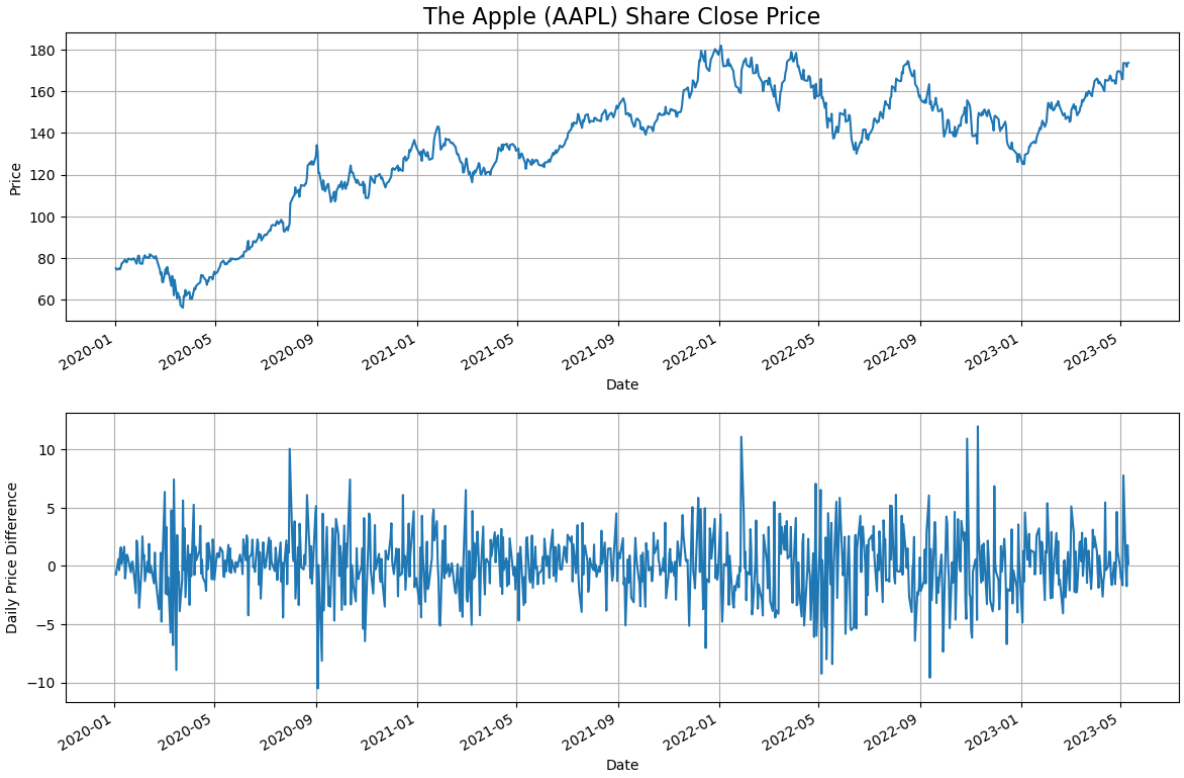
Out[5]:

Date	Close

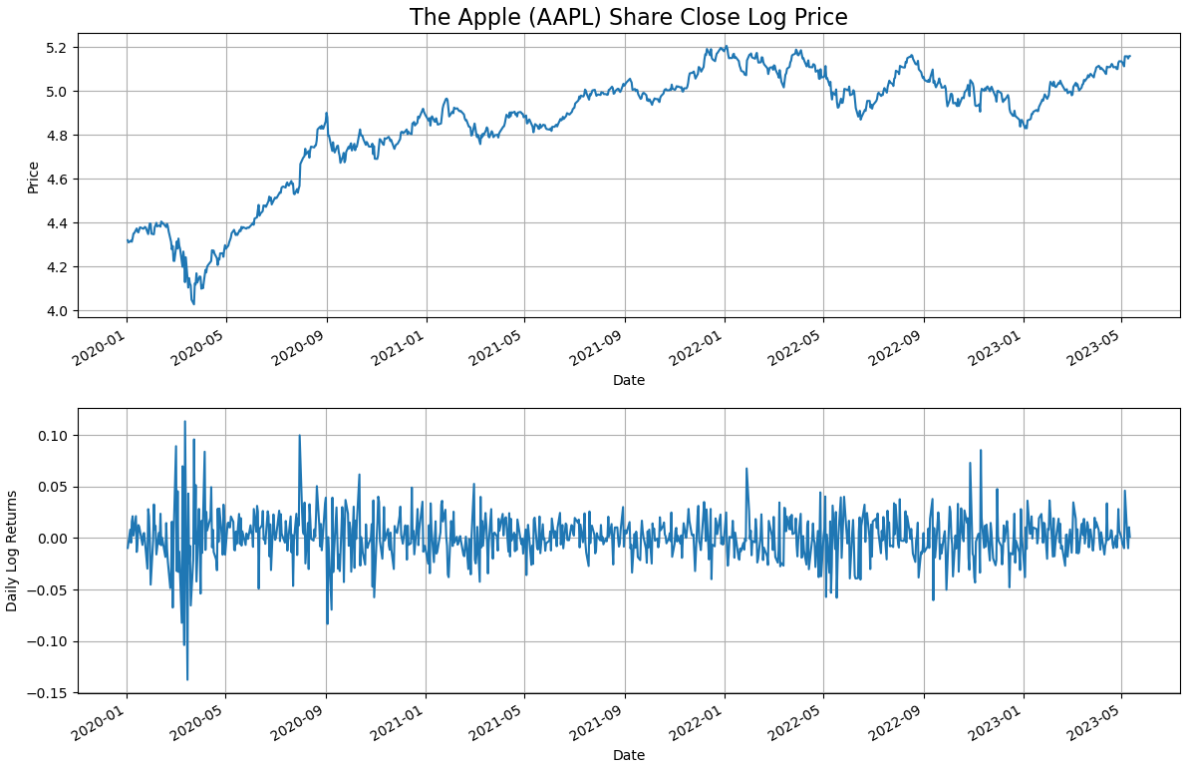
In [6]:
```
# First-order differencing
ap_diff = ap.diff().dropna()
# Log price of AP
ap_lgp = np.log(ap)
# Log Returns of AP
ap_rtn = np.log(ap).diff().dropna()
```

In [7]:

```
plt.figure(figsize=(12,8))

plt.subplot(2, 1, 1)
ap['Close'].plot()
plt.grid()
plt.ylabel("Price")
plt.title("The Apple (AAPL) Share Close Price", fontsize = 16)
plt.subplot(2, 1, 2)
ap_diff['Close'].plot()
plt.grid()
plt.tight_layout(pad=1.5)
plt.ylabel("Daily Price Difference")

plt.savefig("new_images/Apple_(AAPL)_stationary_1")
```



In [8]:
```
plt.figure(figsize=(12,8))

plt.subplot(2, 1, 1)
ap_lgp['Close'].plot()
plt.grid()
plt.ylabel("Price")
plt.title("The Apple (AAPL) Share Close Log Price", fontsize = 16)
plt.subplot(2, 1, 2)
ap_rtn['Close'].plot()
plt.grid()
plt.tight_layout(pad=1.5)
plt.ylabel("Daily Log Returns")

plt.savefig("new_images/Apple_(AAPL)_stationary_2")
```



ARIMA

In [9]:
```
# Get the number of rows to train the model on
training_ap_len = int(np.ceil(len(ap) * .8 ))
# Create the scaled training data set
train_ap = ap[0:int(training_ap_len)]
# First-order differencing
train_ap_diff = train_ap.diff().dropna()
# Log price
train_ap_lgp = np.log(train_ap)
# Log Returns
train_ap_rtn = np.log(train_ap).diff().dropna()
```

In [10]:
```
# Pirce d=0
result = adfuller(train_ap)
print('ADF Statistic: %f' % result[0])
print('p-value: %f' % result[1])
for key, value in result[4].items():
    print('\t%s: %.3f' % (key, value))
```

```
ADF Statistic: -1.578562
p-value: 0.494353
        1%: -3.440
        5%: -2.866
        10%: -2.569
```

In [11]:
```
# Pirce d=1
result = adfuller(train_ap_diff)
print('ADF Statistic: %f' % result[0])
print('p-value: %f' % result[1])
for key, value in result[4].items():
    print('\t%s: %.3f' % (key, value))
```

```
ADF Statistic: -27.641732
p-value: 0.000000
        1%: -3.440
        5%: -2.866
        10%: -2.569
```

In [12]:
```
# Log Pirce d=0
result = adfuller(train_ap_lgp)
print('ADF Statistic: %f' % result[0])
print('p-value: %f' % result[1])
for key, value in result[4].items():
    print('\t%s: %.3f' % (key, value))
```

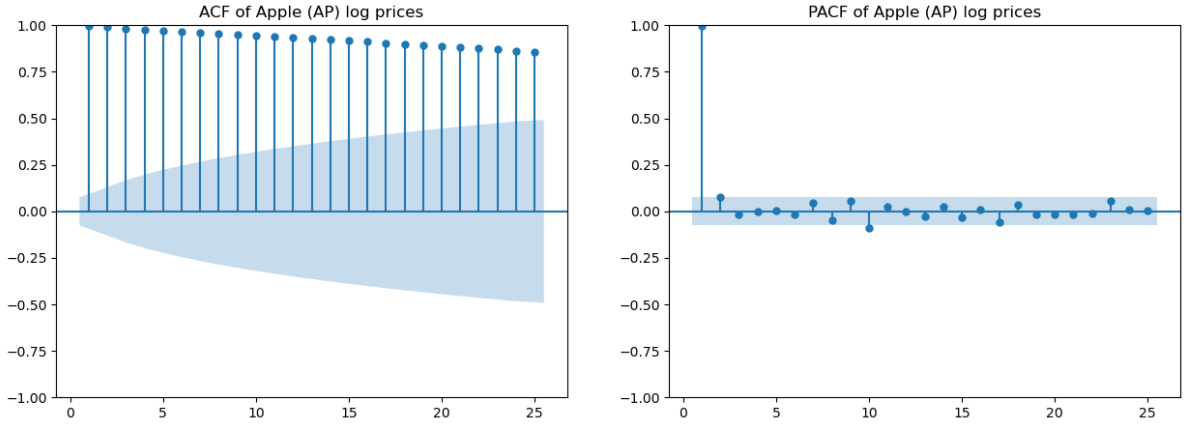
```
ADF Statistic: -1.574681
p-value: 0.496298
        1%: -3.440
        5%: -2.866
        10%: -2.569
```

In [13]:
```
# Log Pirce d=1
result = adfuller(train_ap_rtn)
print('ADF Statistic: %f' % result[0])
print('p-value: %f' % result[1])
for key, value in result[4].items():
    print('\t%s: %.3f' % (key, value))
```

```
ADF Statistic: -8.258065
p-value: 0.000000
        1%: -3.440
        5%: -2.866
        10%: -2.569
```

In [14]:
```
def plot_ACF_PACF(data, lag_num, company_name):
    fig, axes = plt.subplots(1,2,figsize=(15,5))

    fig = plot_acf(data.values, lags = lag_num, zero=False, ax = axes[0],
                   title= 'ACF of ' + company_name + ' log prices')

    fig = plot_pacf(data.values, lags = lag_num, zero=False, ax = axes[1],
                   title= 'PACF of ' + company_name + ' log prices')

    # plt.show()
    plt.savefig("new_images/ACF PACF" + company_name, dpi = 300)
```

In [15]:
```
plot_ACF_PACF(train_ap_lgp, 25, 'Apple (AP)')
```



In [16]:
```
def searchARIMA(data, d, max_p, max_q):
    results = []

    aic = np.zeros((max_p, max_q))
    bic = np.zeros((max_p, max_q))

    for i in range(max_p):
        for j in range(max_q):
            model = ARIMA(data, order=(i, d, j))
            model = ARIMA(data, order=(i, d, j))
            res = model.fit()
            aic[i, j] = res.aic
            bic[i, j] = res.bic

            result_dict = {
                'p': i,
                'q': j,
                'aic': aic[i, j],
                'bic': bic[i, j]
            }
            results.append(result_dict)
            # print('p:', i, ' q:', j, ' aic:', aic[i, j], ' bic:', bic[i, j])

    result_df = pd.DataFrame(results)
    return result_df
```

In [17]:
```
result_df = searchARIMA(train_ap_lgp.values, d = 1, max_p = 10, max_q = 10)
result_df
```

Out[17]:

	p	q	aic	bic
0	0	0	-3179.664473	-3175.148280
1	0	1	-3194.204657	-3185.172271
2	0	2	-3194.055748	-3180.507169
3	0	3	-3192.262784	-3174.198012
4	0	4	-3190.888137	-3168.307171
...	...	...	...	...
95	9	5	-3203.345669	-3135.602773
96	9	6	-3201.034374	-3128.775284
97	9	7	-3197.136715	-3120.361433
98	9	8	-3199.820345	-3118.528870
99	9	9	-3196.085319	-3110.277650

In [18]:
```
min_aic_bic_row = result_df[(result_df['aic'] == result_df['aic'].min()) |
                            (result_df['bic'] == result_df['bic'].min())]
min_aic_bic_row
```

Out[18]:

	p	q	aic	bic
10	1	0	-3195.652373	-3186.619987
25	2	5	-3214.931029	-3178.801485

In [19]:
```
p, d, q = 1, 1, 0
ar_model_ap = ARIMA(train_ap_lgp['Close'], order=(p, d, q))
ar_model_ap = ar_model_ap.fit()
ar_model_ap.summary()
```

```
C:\Users\surface\anaconda3\Lib\site-packages\statsmodels\tsa\base\tsa_model.py:473: ValueWarnin
g: A date index has been provided, but it has no associated frequency information and so will be
ignored when e.g. forecasting.
  self._init_dates(dates, freq)
C:\Users\surface\anaconda3\Lib\site-packages\statsmodels\tsa\base\tsa_model.py:473: ValueWarnin
g: A date index has been provided, but it has no associated frequency information and so will be
ignored when e.g. forecasting.
  self._init_dates(dates, freq)
C:\Users\surface\anaconda3\Lib\site-packages\statsmodels\tsa\base\tsa_model.py:473: ValueWarnin
g: A date index has been provided, but it has no associated frequency information and so will be
ignored when e.g. forecasting.
  self._init_dates(dates, freq)
```

Out[19]:

SARIMAX Results

Dep. Variable:	Close	**No. Observations:**	677
Model:	ARIMA(1, 1, 0)	**Log Likelihood**	1599.826
Date:	Fri, 15 Dec 2023	**AIC**	-3195.652
Time:	21:53:47	**BIC**	-3186.620
Sample:	0	**HQIC**	-3192.155
	- 677		
Covariance Type:	opg		

	coef	std err	z	P>|z|	[0.025	0.975]
ar.L1	-0.1622	0.025	-6.602	0.000	-0.210	-0.114
sigma2	0.0005	1.74e-05	29.622	0.000	0.000	0.001

Ljung-Box (L1) (Q):	0.00	**Jarque-Bera (JB):**	411.05
Prob(Q):	0.96	**Prob(JB):**	0.00
Heteroskedasticity (H):	0.46	**Skew:**	-0.23
Prob(H) (two-sided):	0.00	**Kurtosis:**	6.79

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).

In [20]:
```
# Set the significance level (alpha)
alpha = 0.05

p_values = ar_model_ap.pvalues

significant_predictors = p_values[p_values <= alpha]

print("Significant Predictors:")
print(significant_predictors)
```

```
Significant Predictors:
ar.L1      4.042952e-11
sigma2    7.791997e-193
dtype: float64
```

In [21]:
```
predicted_original_train_ap = ar_model_ap.predict(start=train_ap_lgp.index[0],
                                                  end=train_ap_lgp.index[-1],
                                                  dynamic=False)
predicted_original_train_ap = np.exp(predicted_original_train_ap)
```

In [22]:
```
predicted_original_train_ap = pd.DataFrame(predicted_original_train_ap)

train_val_ap = ap[:int(training_ap_len)]
train_val_ap = pd.merge(train_val_ap, predicted_original_train_ap,
                        left_index=True, right_index=True)
train_val_ap = train_val_ap.rename(columns={'predicted_mean': 'Prediction'})
train_val_ap
```

Out[22]:

Date	Close	Prediction
2020-01-02	75.087502	1.000000
2020-01-03	74.357498	75.087501
2020-01-06	74.949997	74.475393
2020-01-07	74.597504	74.853596
2020-01-08	75.797501	74.654552
...	...	...
2022-09-01	157.960007	157.492830
2022-09-02	155.809998	157.839770
2022-09-06	154.529999	156.156649
2022-09-07	155.960007	154.736850
2022-09-08	154.460007	155.727218

677 rows × 2 columns

In [23]:
```
train_mse = mean_squared_error(train_val_ap['Close'], train_val_ap['Prediction'])
train_rmse = np.sqrt(train_mse)
print("The MSE of the Trainning set is", train_mse)
print("The RMSE of the Trainning set is", train_rmse)
```

```
The MSE of the Trainning set is 15.267239201819622
The RMSE of the Trainning set is 3.907331468127528
```

In [24]:
```
# Create the scaled training data set
test_ap = ap[int(training_ap_len):]
# Log price
test_ap_lgp = np.log(test_ap)

forecast_ap = ar_model_ap.get_forecast(steps=len(test_ap_lgp))

predicted_values_ap = forecast_ap.predicted_mean
predicted_original_ap = np.exp(predicted_values_ap)
predicted_original_ap = np.array(predicted_original_ap)
```

```
C:\Users\surface\anaconda3\Lib\site-packages\statsmodels\tsa\base\tsa_model.py:836: ValueWarnin
g: No supported index is available. Prediction results will be given with an integer index begin
ning at `start`.
  return get_prediction_index(
C:\Users\surface\anaconda3\Lib\site-packages\statsmodels\tsa\base\tsa_model.py:836: FutureWarnin
g: No supported index is available. In the next version, calling this method in a model without
a supported index will result in an exception.
  return get_prediction_index(
```

In [25]:
```
predicted_original_ap = pd.DataFrame(index=test_ap_lgp.index, columns=['Prediction'],
                                     data=predicted_original_ap)

test_ap = pd.merge(test_ap, predicted_original_ap,
                   left_index=True, right_index=True)
test_ap
```

Out[25]:

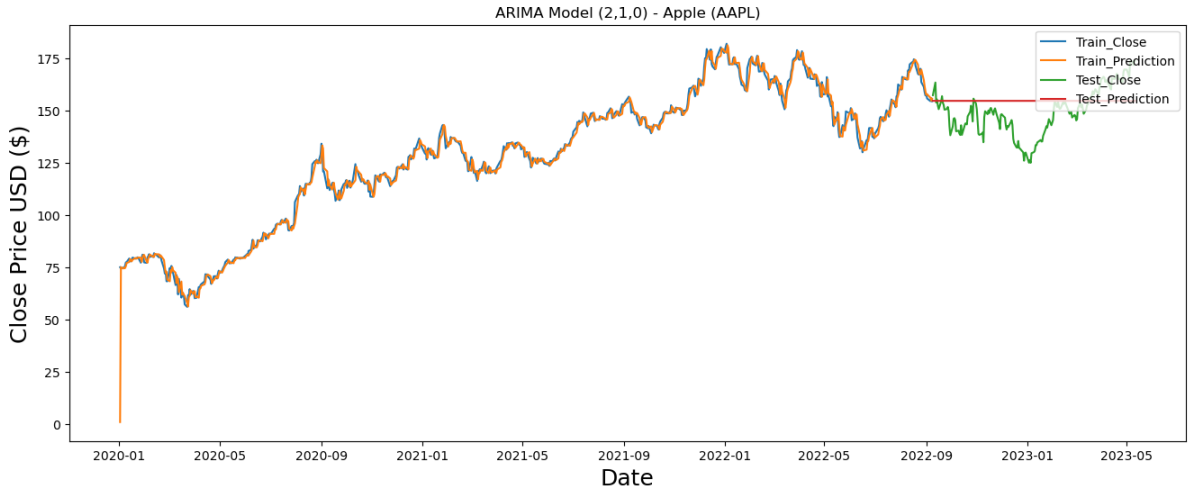
Date	Close	Prediction
2022-09-09	157.369995	154.702266
2022-09-12	163.429993	154.662955
2022-09-13	153.839996	154.669329
2022-09-14	155.309998	154.668296
2022-09-15	152.369995	154.668463
...	...	...
2023-05-05	173.570007	154.668440
2023-05-08	173.500000	154.668440
2023-05-09	171.770004	154.668440
2023-05-10	173.559998	154.668440
2023-05-11	173.750000	154.668440

169 rows × 2 columns

In [26]:
```
test_mse = mean_squared_error(test_ap['Close'], test_ap['Prediction'])
test_rmse = np.sqrt(test_mse)
print("The MSE of the Test set is", test_mse)
print("The RMSE of the Test set is", test_rmse)
```

```
The MSE of the Test set is 151.67952046747203
The RMSE of the Test set is 12.315823986541544
```

In [27]:
```
# Visualize the data
plt.figure(figsize=(16,6))
plt.title('ARIMA Model (2,1,0) - Apple (AAPL)')
plt.xlabel('Date', fontsize=18)
plt.ylabel('Close Price USD ($)', fontsize=18)
plt.plot(train_val_ap[['Close', 'Prediction']])
plt.plot(test_ap[['Close', 'Prediction']])
plt.legend(['Train_Close', 'Train_Prediction','Test_Close', 'Test_Prediction'], loc='upper right')
#plt.show()
plt.savefig("new_images/Apple_(AAPL)_ARIMA_1")
```



LSTM

In [28]:
```
scaler_ap = MinMaxScaler(feature_range=(0,1))
scaled_ap = scaler_ap.fit_transform(ap)
```

In [29]:
```
# Get the number of rows to train the model on
training_ap_len = int(np.ceil( len(scaled_ap) * .8 ))
training_ap_len
```

Out[29]: 677

In [30]:
```
# Create the scaled training data set
train_ap = scaled_ap[0:int(training_ap_len), :]
```

In [31]:
```
def Split_train_data_with_lookback_window(train_data, timestamps):
    x_train = []
    y_train = []

    for i in range(timestamps, len(train_data)):
        x_train.append(train_data[i-10:i, 0])
        y_train.append(train_data[i, 0])
        if i<= timestamps+1:
            print(x_train)
            print(y_train)
            print()

    # Convert the x_train and y_train to numpy arrays
    x_train, y_train = np.array(x_train), np.array(y_train)

    # Reshape the data
    x_train = np.reshape(x_train, (x_train.shape[0], x_train.shape[1], 1))

    return x_train, y_train
```

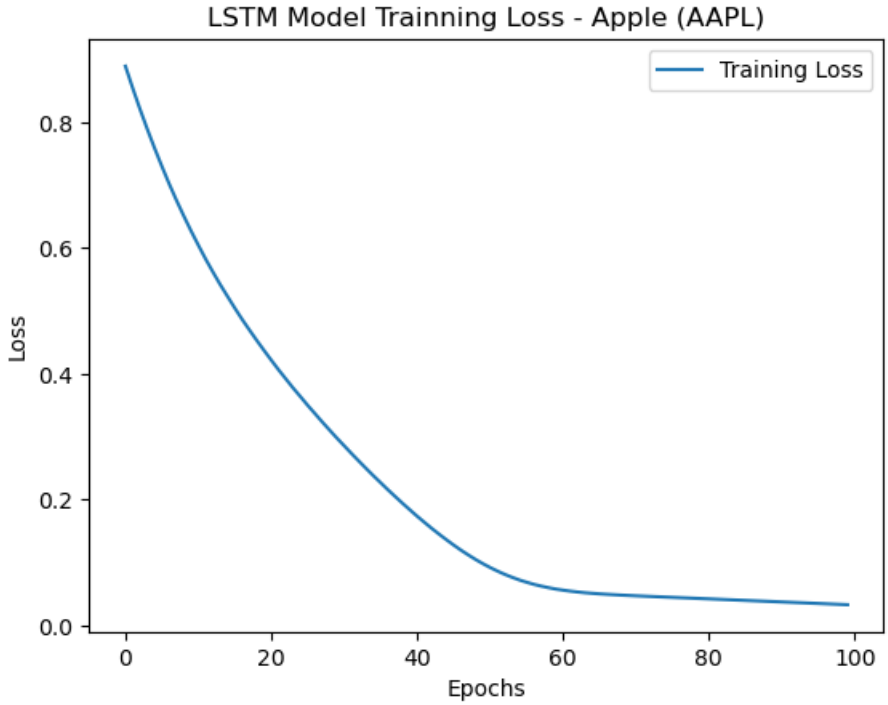
In [32]:
```
x_train_ap, y_train_ap = Split_train_data_with_lookback_window(train_ap, 10)
```

```
[array([0.15085277, 0.14505529, 0.14976075, 0.14696135, 0.15649137,
       0.16927753, 0.17066729, 0.18383068, 0.17533306, 0.17267259])]
[0.18041574483384826]

[array([0.15085277, 0.14505529, 0.14976075, 0.14696135, 0.15649137,
       0.16927753, 0.17066729, 0.18383068, 0.17533306, 0.17267259]), array([0.14505529, 0.149760
75, 0.14696135, 0.15649137, 0.16927753,
       0.17066729, 0.18383068, 0.17533306, 0.17267259, 0.18041574])]
[0.18041574483384826, 0.18734492638202815]
```

In [33]:
```
# Build the LSTM model
lstm_model_ap = Sequential()
lstm_model_ap.add(LSTM(4, input_shape= (x_train_ap.shape[1], 1)))
lstm_model_ap.add(Dense(1))
# Compile the model
lstm_model_ap.compile(optimizer='adam', loss='mean_squared_error')
# Train the model
history = lstm_model_ap.fit(x_train_ap, y_train_ap, batch_size=256, epochs=100, verbose=2)
```

```
Epoch 1/100
3/3 - 5s - loss: 0.8889 - 5s/epoch - 2s/step
Epoch 2/100
3/3 - 0s - loss: 0.8540 - 23ms/epoch - 8ms/step
Epoch 3/100
3/3 - 0s - loss: 0.8206 - 21ms/epoch - 7ms/step
Epoch 4/100
3/3 - 0s - loss: 0.7889 - 22ms/epoch - 7ms/step
Epoch 5/100
3/3 - 0s - loss: 0.7586 - 23ms/epoch - 8ms/step
Epoch 6/100
3/3 - 0s - loss: 0.7297 - 25ms/epoch - 8ms/step
Epoch 7/100
3/3 - 0s - loss: 0.7019 - 23ms/epoch - 8ms/step
Epoch 8/100
3/3 - 0s - loss: 0.6758 - 34ms/epoch - 11ms/step
Epoch 9/100
3/3 - 0s - loss: 0.6510 - 24ms/epoch - 8ms/step
Epoch 10/100
```

In [34]:
```
# Plot the training loss - Convergence
plt.plot(history.history['loss'], label='Training Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.title('LSTM Model Trainning Loss - Apple (AAPL)')
plt.legend()
#plt.show()
plt.savefig("new_images/LSTM Model Trainning Loss - Apple (AAPL)")
```



In [35]:
```
y_train_ap = ap[10:training_ap_len].values
# Get the models predicted price values
train_pred_ap = lstm_model_ap.predict(x_train_ap)
train_pred_ap = scaler_ap.inverse_transform(train_pred_ap)

train_val_ap = ap[10:training_ap_len]
train_val_ap['Prediction'] = train_pred_ap
train_val_ap
```

```
21/21 [==============================] - 1s 3ms/step

C:\Users\surface\AppData\Local\Temp\ipykernel_10576\1390658575.py:7: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy (https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy)
  train_val_ap['Prediction'] = train_pred_ap
```

Out[35]:

Date	Close	Prediction
2020-01-16	78.809998	116.177139
2020-01-17	79.682503	116.301277
2020-01-21	79.142502	116.443954
2020-01-22	79.425003	116.620178
2020-01-23	79.807503	116.781670
...	...	...
2022-09-01	157.960007	141.753510
2022-09-02	155.809998	141.211136
2022-09-06	154.529999	140.900467
2022-09-07	155.960007	140.590561
2022-09-08	154.460007	140.115280

667 rows × 2 columns

In [36]:
```
train_mse = mean_squared_error(train_val_ap['Close'], train_val_ap['Prediction'])
train_rmse = np.sqrt(train_mse)
print("The MSE of the Trainning set is", train_mse)
print("The RMSE of the Trainning set is", train_rmse)
```

```
The MSE of the Trainning set is 522.5024792895756
The RMSE of the Trainning set is 22.85831313307208
```

In [37]:
```
# get test data set and split into X and y
def Split_test_data_with_lookback_window(scaled_data, original_data, training_data_len, timestamps
    # Create the testing data set
    test_data = scaled_data[training_data_len - 10: , :]
    # Create the data sets x_test and y_test
    x_test = []
    y_test = original_data[training_data_len:].values

    for i in range(timestamps, len(test_data)):
        x_test.append(test_data[i-timestamps:i, 0])

    # Convert the data to a numpy array
    x_test = np.array(x_test)

    # Reshape the data
    x_test = np.reshape(x_test, (x_test.shape[0], x_test.shape[1], 1 ))

    return x_test, y_test
```

In [38]:
```
x_test_ap, y_test_ap = Split_test_data_with_lookback_window(scaled_ap, ap, training_ap_len, 10)
```

In [39]:
```
# Get the models predicted price values
pred_ap = lstm_model_ap.predict(x_test_ap)
pred_ap = scaler_ap.inverse_transform(pred_ap)

test_ap = ap[training_ap_len:]
test_ap['Prediction'] = pred_ap

# Get MSE and RMSE
test_mse_ap = np.mean(((pred_ap - y_test_ap) ** 2))
test_rmse_ap = np.sqrt(test_mse_ap)
print("The MSE of the Test set is", test_mse_ap)
print("The RMSE of the Test set is", test_rmse_ap)
```

```
6/6 [==============================] - 0s 2ms/step
The MSE of the Test set is 234.2003464356844
The RMSE of the Test set is 15.303605667805362

C:\Users\surface\AppData\Local\Temp\ipykernel_10576\2423058360.py:6: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/in
dexing.html#returning-a-view-versus-a-copy (https://pandas.pydata.org/pandas-docs/stable/user_gu
ide/indexing.html#returning-a-view-versus-a-copy)
  test_ap['Prediction'] = pred_ap
```

In [40]:

```
# Visualize the data
plt.figure(figsize=(16,6))
plt.title('LSTM Model - Apple (AAPL)')
plt.xlabel('Date', fontsize=18)
plt.ylabel('Close Price USD ($)', fontsize=18)
plt.plot(train_val_ap[['Close', 'Prediction']])
plt.plot(test_ap[['Close', 'Prediction']])
plt.legend(['Train_Close', 'Train_Prediction','Test_Close', 'Test_Prediction'], loc='upper right')
#plt.show()
plt.savefig("new_images/LSTM Model - Apple (AAPL)")
```