In [2]:
```
import numpy as np
import pandas as pd

import matplotlib.pyplot as plt
# plt.style.use("dark_background")
import seaborn as sns
import statsmodels.api as sm
import math
import warnings
warnings.filterwarnings('ignore')

# reviews_sample.columns.str.strip().str.lower().str.replace(' ', '_')
```

1. Load & Transform the Data [20 points]

a) [15 points]

In [12]:
```
# create a function 'load_Data' to load the data
def load_data():
    covid_raw = pd.read_csv("time_series_covid19_confirmed_global.csv", sep=",")
    covid_raw.columns.values[1] = ""
    covid_raw['cum_sum'] = covid_raw['8/21/20']
    covid_raw.sort_values(by=['cum_sum'], inplace=True, ascending=False)
    covid = covid_raw.head().T
    covid.columns = covid.iloc[1]
    covid = covid.iloc[4:-1]
    covid.index = pd.to_datetime(covid.index)
    # decrease each row from previous
    covid = covid.diff()
    # drop first row
    covid = covid.iloc[1:]
    return covid

covid = load_data()
covid
```

Out[12]:

	US	Brazil	India	Russia	South Africa
2020-01-23	0	0	0	0	0
2020-01-24	1	0	0	0	0
2020-01-25	0	0	0	0	0
2020-01-26	3	0	0	0	0
2020-01-27	0	0	0	0	0
...	...	...	...	...	...
2020-08-17	35112	19373	55018	4839	2541
2020-08-18	44091	47784	64572	4718	2258
2020-08-19	47408	49298	69672	4790	3916
2020-08-20	44023	45323	68900	4767	3880
2020-08-21	48693	30355	69876	4838	3398

212 rows × 5 columns

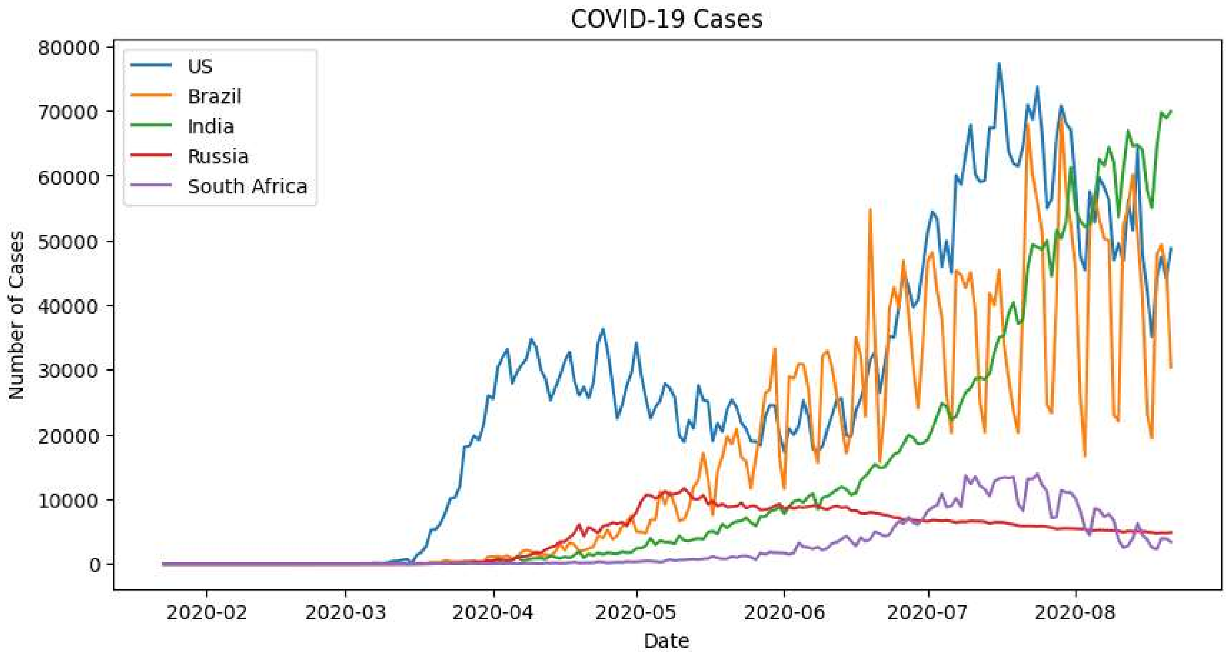
US, Brazil, India, Russia and South Africa are the top 5 countries with the most cumulative cases as of August 21, 2020, sorted in descending order.

b) [5 points]

In [13]:

```
# create a function 'plot_data' to plot the data
def plot_data(covid):
    plt.figure(figsize=(10, 5))
    plt.plot(covid)
    plt.legend(covid.columns)
    plt.xlabel("Date")
    plt.ylabel("Number of Cases")
    plt.title("COVID-19 Cases")
    plt.show()


plot_data(covid)
```



We can see a considerable seasonal pattern for US and Brazil, but for India, Russia and South Africa, it is low.

2. Extract Seasonal Components [15 points]

a) [10 points]

In [14]:

```
# `seasonal_decompose` function from the `statsmodels` package
def sea_decomp(covid):
    seasonal_df = pd.DataFrame()
    # take for all countries
    for country in covid.columns:
        decomposition = sm.tsa.seasonal_decompose(covid[country], model='additive')
        seasonal_df[country] = decomposition.seasonal

    seasonal_df.index = pd.to_datetime(seasonal_df.index)
    return seasonal_df

seasonal_df = sea_decomp(covid)
seasonal_df
```

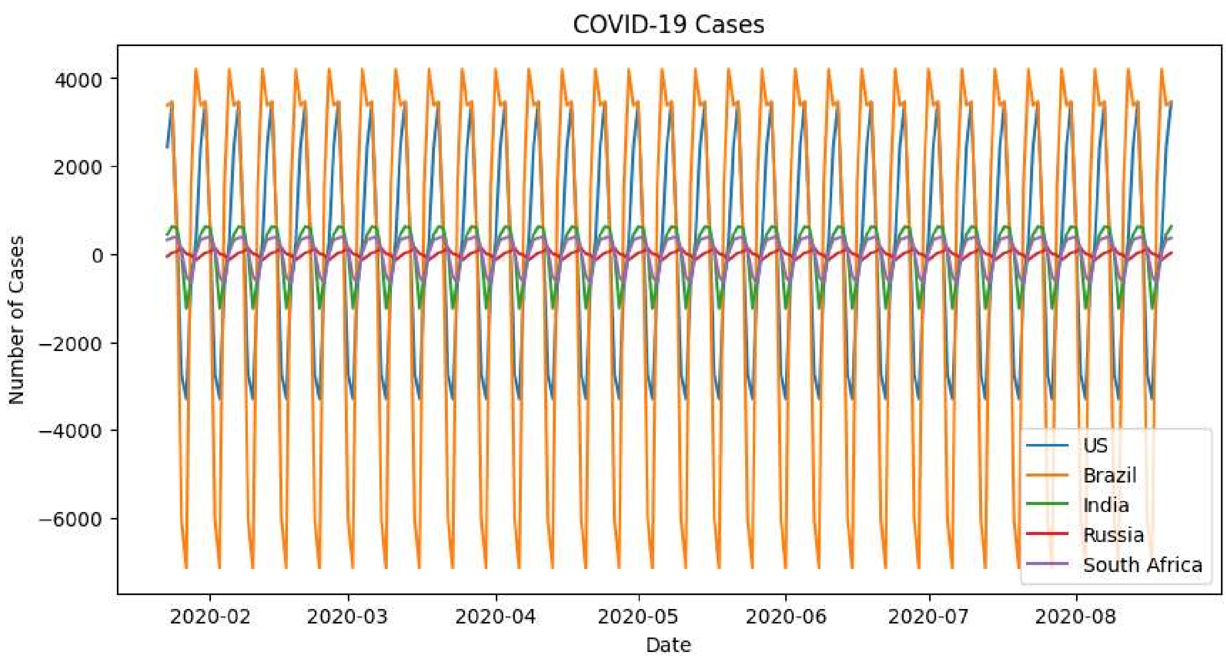
Out[14]:

	US	Brazil	India	Russia	South Africa
2020-01-23	2431.761670	3380.626554	441.179428	-54.886371	322.986535
2020-01-24	3446.796153	3457.641332	621.396176	23.689984	362.434811
2020-01-25	578.564626	586.665963	594.066127	55.034811	391.346141
2020-01-26	-2728.454422	-6031.950950	46.655454	137.908703	76.880131
2020-01-27	-3293.854422	-7144.674760	-1234.673118	1.842036	-507.496059
...	...	...	...	...	...
2020-08-17	-3293.854422	-7144.674760	-1234.673118	1.842036	-507.496059
2020-08-18	-719.521088	1549.577621	-544.749308	-28.929392	-662.877011
2020-08-19	284.707483	4202.114239	76.125240	-134.659770	16.725452
2020-08-20	2431.761670	3380.626554	441.179428	-54.886371	322.986535
2020-08-21	3446.796153	3457.641332	621.396176	23.689984	362.434811

212 rows × 5 columns

In [15]:

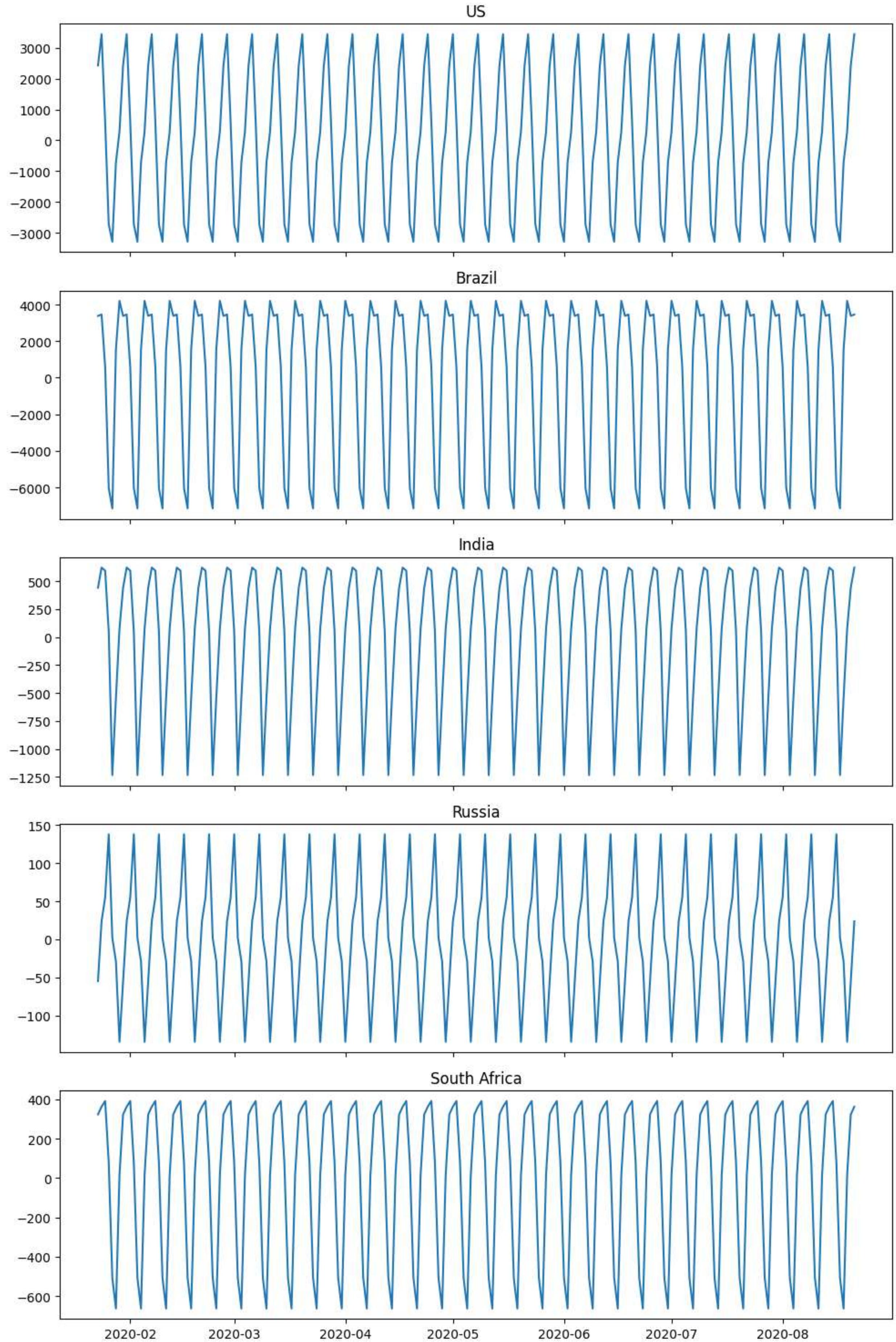
```
plot_data(seasonal_df)
```



b) [5 points]

In [16]:

```
# plot one line for each country, 5 subplots
fig, axes = plt.subplots(5, 1, figsize=(10, 15), sharex=True)
for i, country in enumerate(seasonal_df.columns):
    axes[i].plot(seasonal_df[country])
    axes[i].set_title(country)
plt.tight_layout()
plt.show()
```



We plotted the seasonal components of number of daily cases for each of the 5 countries.

3. Time Series Similarities [40 points]

3.1 Euclidean Distance [20 points]

a) [15 points]

In [20]:
```
# Complete a function, ‘calc_euclidean_dist’, that accepts a `pd.DataFrame`,
# whose columns are time series for each country, and that returns all pairwise Euclid
# Distance among these time series

def calc_euclidean_dist(covid):
    index = covid.columns
    dist_df = pd.DataFrame(index=index, columns=index)
    for country in covid.columns:
        for country2 in covid.columns:
            dist_df[country][country2] = (np.sqrt(np.sum(
                np.square(covid[country2] - covid[country]), axis=0)))

    return dist_df

calc_euclidean_dist(covid)
```

Out[20]:

	US	Brazil	India	Russia	South Africa
US	0.0	233760.757213	272344.138927	433638.331574	436238.175972
Brazil	233760.757213	0.0	178779.66374	306032.283923	304919.698741
India	272344.138927	178779.66374	0.0	316862.76763	303936.538967
Russia	433638.331574	306032.283923	316862.76763	0.0	67392.593681
South Africa	436238.175972	304919.698741	303936.538967	67392.593681	0.0

b) [5 points]

In [21]:
```
euc_dist = calc_euclidean_dist(seasonal_df)
euc_dist
```

Out[21]:

	US	Brazil	India	Russia	South Africa
US	0.0	37616.752035	27032.887714	33986.305519	30084.544171
Brazil	37616.752035	0.0	57583.437987	63663.896821	60839.376478
India	27032.887714	57583.437987	0.0	9102.412727	4490.020448
Russia	33986.305519	63663.896821	9102.412727	0.0	5658.222387
South Africa	30084.544171	60839.376478	4490.020448	5658.222387	0.0

3.2 Cosine Similarity [20 points]

a) [15 points]

In [23]:
```
# Complete a function, ‘calc_cos_sim’, that accepts a `pd.DataFrame`, whose
# columns are the time series for each country, and that returns all pairwise Cosine S
# among these time series

def calc_cos_sim(covid):
    index = covid.columns
    cos_df = pd.DataFrame(index=index, columns=index)
    for country in covid.columns:
        for country2 in covid.columns:
            cos_df[country][country2] = \
            (np.dot(covid[country2], covid[country]) /
            (np.linalg.norm(covid[country2]) * np.linalg.norm(covid[country])))

    return cos_df

calc_cos_sim(covid)
```

Out[23]:

	US	Brazil	India	Russia	South Africa
US	1.0	0.898664	0.84716	0.80474	0.884909
Brazil	0.898664	1.0	0.878452	0.763523	0.871214
India	0.84716	0.878452	1.0	0.590388	0.809944
Russia	0.80474	0.763523	0.590388	1.0	0.638246
South Africa	0.884909	0.871214	0.809944	0.638246	1.0

b) [5 points]

In [24]:
```
cos_sim = calc_cos_sim(seasonal_df)
cos_sim
```

Out[24]:

	US	Brazil	India	Russia	South Africa
US	1.0	0.868859	0.783851	-0.325065	0.664261
Brazil	0.868859	1.0	0.632741	-0.629987	0.403198
India	0.783851	0.632741	1.0	0.092292	0.917529
Russia	-0.325065	-0.629987	0.092292	1.0	0.174437
South Africa	0.664261	0.403198	0.917529	0.174437	1.0

4. Dynamic Time Warping (DTW) Cost [25 points]

4.1 Define a Function to Calculate DTW Cost [10 points]

a) [10 points]

In [25]:
```
# implement a function, 'calc_pairwise_dtw_cost',
# that computes the Dynamic Time Warping DTW cost for two time series.

def calc_pairwise_dtw_cost(X, Y, ret_matrix):
    # create a cost matrix
    cost_matrix = np.zeros((len(X), len(Y)))
    # fill the first row and column
    cost_matrix[0, 0] = (X[0] - Y[0])**2
    for i in range(1, len(X)):
        cost_matrix[i, 0] = cost_matrix[i-1, 0] + (X[i] - Y[0])**2
    for j in range(1, len(Y)):
        cost_matrix[0, j] = cost_matrix[0, j-1] + (X[0] - Y[j])**2
    # fill the rest of the matrix
    for i in range(1, len(X)):
        for j in range(1, len(Y)):
            cost_matrix[i, j] = (X[i] - Y[j])**2 + \
            min(cost_matrix[i-1, j], cost_matrix[i, j-1], cost_matrix[i-1, j-1])

    if ret_matrix:
        return cost_matrix
    else:
        # return the last element of the matrix
        return cost_matrix[-1, -1]
```

4.2 Compute Pairwise DTW Cost [15 points]

a) [10 points]

In [26]:
```
# Complete a function, 'calc_dtw_cost', that accepts a `pd.DataFrame`, whose
# columns are the time series for each country, and that returns all pairwise DTW Dist
# among these time series

def calc_dtw_cost(covid):
    index = covid.columns
    dtw_df = pd.DataFrame(index=index, columns=index)
    for country in covid.columns:
        for country2 in covid.columns:
            dtw_df[country][country2] \
                = calc_pairwise_dtw_cost(covid[country2], covid[country], False)

    return dtw_df
```

In [27]:
```
calc_dtw_cost(covid)
```

Out[27]:

	US	Brazil	India	Russia	South Africa
US	0.0	9575974038.0	5187397134.0	174074662446.0	139515939601.0
Brazil	9575974038.0	0.0	14309884215.0	83618108875.0	65427030728.0
India	5187397134.0	14309884215.0	0.0	99276257414.0	87289503477.0
Russia	174074662446.0	83618108875.0	99276257414.0	0.0	163867116.0
South Africa	139515939601.0	65427030728.0	87289503477.0	163867116.0	0.0

b) [5 points]

In [38]:

```
# use this function to calculate the pairwise DTW costs between seasonal
# patterns. take the square root so that we can compare it with the Euclidean Distance
# takes about 30 seconds to run

dtw = calc_dtw_cost(seasonal_df)
```

In [39]:

```
dtw
```

Out[39]:

	US	Brazil	India	Russia	South Afri
US	0.0	1016218295.595645	555353942.818118	1045061751.973515	784925121.8031
Brazil	1016218295.595645	0.0	2851644273.689343	3827651121.885218	3265345080.1322
India	555353942.818118	2851644273.689343	0.0	59099617.140716	19922165.9622
Russia	1045061751.973515	3827651121.885218	59099617.140716	0.0	18139901.8803
South Africa	784925121.803171	3265345080.132234	19922165.962264	18139901.880343	(

In [41]:

```
# sqrt the dtw matrix except Index column
dtw_sqrt = dtw.copy()

for i in range(0, len(dtw_sqrt)):
    for j in range(0, len(dtw_sqrt)):
        dtw_sqrt.iloc[i][j] = np.sqrt(dtw_sqrt.iloc[i][j]).round(3)
```

In [42]:

```
dtw_sqrt
```

Out[42]:

	US	Brazil	India	Russia	South Africa
US	0.0	31878.179	23565.949	32327.415	28016.515
Brazil	31878.179	0.0	53400.789	61868.014	57143.198
India	23565.949	53400.789	0.0	7687.628	4463.425
Russia	32327.415	61868.014	7687.628	0.0	4259.096
South Africa	28016.515	57143.198	4463.425	4259.096	0.0

From these analysis, we can conclude that:

- India, Russia and South Africa have similar seasonal patterns. This is be because their Euclidean and DTW distances are less.
- The seasonal patterns of US and Brazil are different from the rest.
- I have plotted a heat map of Euclidean distance, Cosine Similarity and DTW distance below.
- The plot show that Euclidean Distance and DTW Cost calculations tell almost the same story.

In [43]:
```
# 3 subplots of heatmaps
fig, axes = plt.subplots(1, 3, figsize=(15, 5))
sns.heatmap(euc_dist.astype(float), cmap='YlGnBu', ax=axes[0])
axes[0].set_title("Euclidean Distance")
sns.heatmap(cos_sim.astype(float), cmap='YlGnBu', ax=axes[1])
axes[1].set_title("Cosine Similarity")
sns.heatmap(dtw_sqrt.astype(float), cmap='YlGnBu', ax=axes[2])
axes[2].set_title("DTW Distance")
plt.tight_layout()
plt.show()
```