MPI Analysis

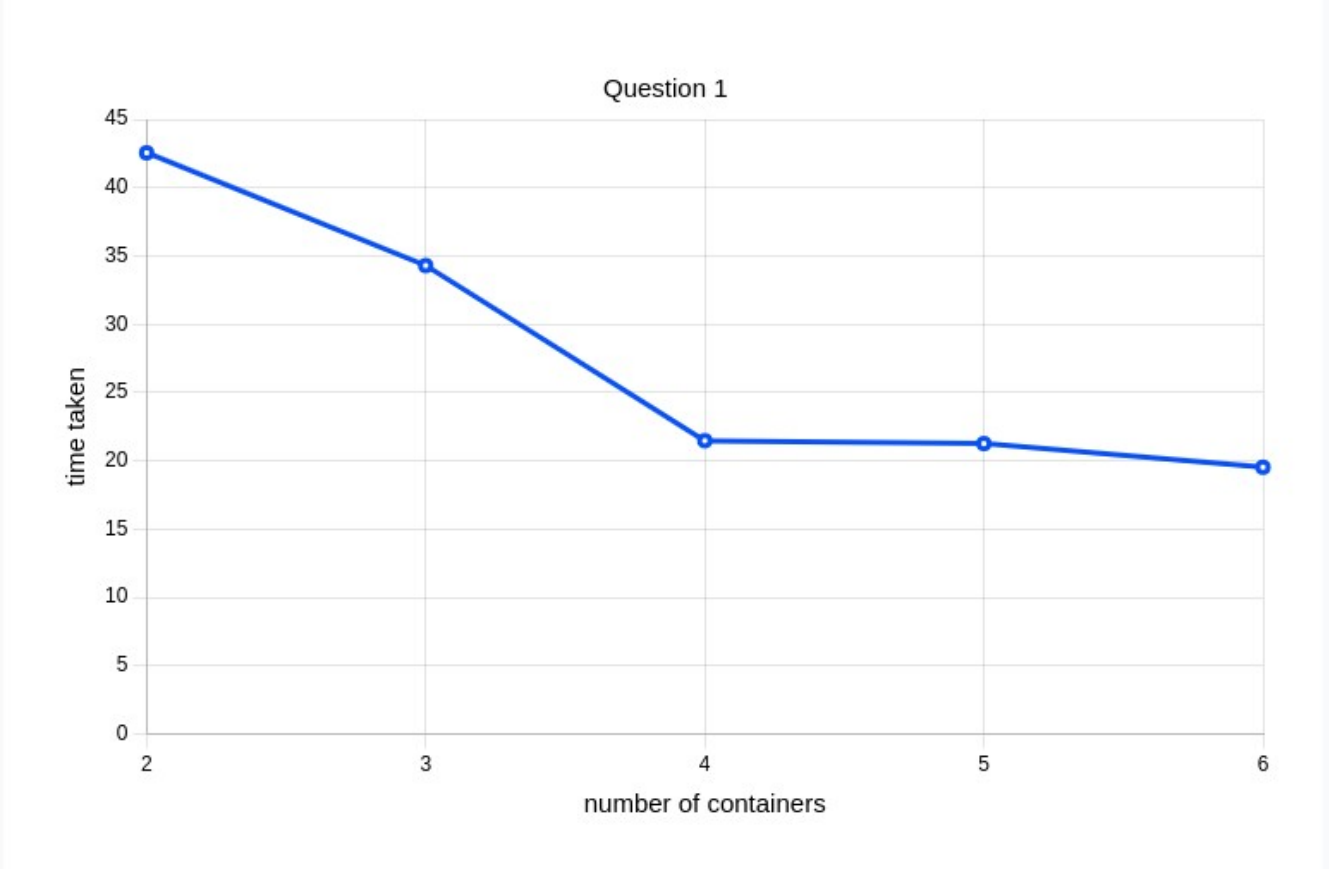
Question 1

```
root@f36a2b313128:/T2_files/implementation/Q1# nano ~/machinefile
root@f36a2b313128:/T2_files/implementation/Q1# mpiexec -n 2 -machinefile ~/machinefile python -m mpi4py
T3.py
received from Worker slave 1
                                          0     1
0                      Southwest Airlines Co.  2326
1                      American Airlines Inc.   759
2                           Republic Airlines   704
3                       United Air Lines Inc.   633
4                             JetBlue Airways   487
5    GoJet Airlines, LLC d/b/a United Express   428
6                            Spirit Air Lines   316
7                       SkyWest Airlines Inc.   297
8                        Delta Air Lines Inc.   295
9                 Air Wisconsin Airlines Corp   286
10                               Comair Inc.   202
11  Commutair Aka Champlain Enterprises, Inc.   202
12                          Mesa Airlines Inc.   160
13                                Envoy Air   135
14                Capital Cargo International   132
15                      Alaska Airlines Inc.   127
16                         Endeavor Air Inc.    80
17                      Frontier Airlines Inc.    79
18                               Allegiant Air    50
19                                 Horizon Air    42
20                      Hawaiian Airlines Inc.    36
0    Southwest Airlines Co.
1                      2326
Name: 18, dtype: object
time taken with 1 slaves (MPI execution): 42.55 second(s)
Worker 1 is assigned chunk info [6311870, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
root@f36a2b313128:/T2_files/implementation/Q1# mpiexec -n 3 -machinefile ~/machinefile python -m mpi4py
T3.py
Worker 1 is assigned chunk info [3155935, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
received from Worker slave 1
received from Worker slave 2
                                          0     1
0                      Southwest Airlines Co.  2326
1                      American Airlines Inc.   759
2                           Republic Airlines   704
3                       United Air Lines Inc.   633
4                             JetBlue Airways   487
5    GoJet Airlines, LLC d/b/a United Express   428
6                            Spirit Air Lines   316
7                       SkyWest Airlines Inc.   297
8                        Delta Air Lines Inc.   295
9                 Air Wisconsin Airlines Corp   286
10                               Comair Inc.   202
11  Commutair Aka Champlain Enterprises, Inc.   202
12                          Mesa Airlines Inc.   160
13                                Envoy Air   135
14                Capital Cargo International   132
15                      Alaska Airlines Inc.   127
16                         Endeavor Air Inc.    80
17                      Frontier Airlines Inc.    79
18                               Allegiant Air    50
19                                 Horizon Air    42
20                      Hawaiian Airlines Inc.    36
0    Southwest Airlines Co.
1                      2326
Name: 18, dtype: object
```

```
time taken with 2 slaves (MPI execution): 34.3 second(s)
Worker 2 is assigned chunk info [None, 3155936] ../../Combined_Flights_2021.csv
Worker slave 2 is done. Sending back to master
root@f36a2b313128:/T2_files/implementation/Q1# mpiexec -n 4 -machinefile ~/machinefile python -m mpi4py
T3.py
Worker 1 is assigned chunk info [2103956, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
Worker 2 is assigned chunk info [2103957, 2103957] ../../Combined_Flights_2021.csv
Worker slave 2 is done. Sending back to master
received from Worker slave 1
received from Worker slave 2
received from Worker slave 3
                                          0     1
0                      Southwest Airlines Co.  2326
1                      American Airlines Inc.   759
2                           Republic Airlines   704
3                       United Air Lines Inc.   633
4                             JetBlue Airways   487
5    GoJet Airlines, LLC d/b/a United Express   428
6                            Spirit Air Lines   316
7                       SkyWest Airlines Inc.   297
8                        Delta Air Lines Inc.   295
9                 Air Wisconsin Airlines Corp   286
10                                 Comair Inc.   202
11  Commutair Aka Champlain Enterprises, Inc.   202
12                         Mesa Airlines Inc.   160
13                                 Envoy Air   135
14                Capital Cargo International   132
15                       Alaska Airlines Inc.   127
16                          Endeavor Air Inc.    80
17                     Frontier Airlines Inc.    79
18                               Allegiant Air    50
19                                 Horizon Air    42
20                     Hawaiian Airlines Inc.    36
0    Southwest Airlines Co.
1                      2326
Name: 18, dtype: object
time taken with 3 slaves (MPI execution): 21.48 second(s)
Worker 3 is assigned chunk info [None, 4207914] ../../Combined_Flights_2021.csv
Worker slave 3 is done. Sending back to master
root@f36a2b313128:/T2_files/implementation/Q1# mpiexec -n 5 -machinefile ~/machinefile python -m mpi4py
T3.py
Worker 1 is assigned chunk info [1577967, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
Worker 3 is assigned chunk info [1577968, 3155936] ../../Combined_Flights_2021.csv
Worker slave 3 is done. Sending back to master
Worker 2 is assigned chunk info [1577968, 1577968] ../../Combined_Flights_2021.csv
Worker slave 2 is done. Sending back to master
received from Worker slave 1
received from Worker slave 2
received from Worker slave 3
received from Worker slave 4
                                          0     1
0                      Southwest Airlines Co.  2326
1                      American Airlines Inc.   759
2                           Republic Airlines   704
3                       United Air Lines Inc.   633
4                             JetBlue Airways   487
5    GoJet Airlines, LLC d/b/a United Express   428
6                            Spirit Air Lines   316
7                       SkyWest Airlines Inc.   297
8                        Delta Air Lines Inc.   295
9                 Air Wisconsin Airlines Corp   286
10                                 Comair Inc.   202
11  Commutair Aka Champlain Enterprises, Inc.   202
12                         Mesa Airlines Inc.   160
13                                 Envoy Air   135
14                Capital Cargo International   132
15                       Alaska Airlines Inc.   127
16                          Endeavor Air Inc.    80
17                     Frontier Airlines Inc.    79
18                               Allegiant Air    50
```

```
19                              Horizon Air    42
20                    Hawaiian Airlines Inc.    36
0    Southwest Airlines Co.
1                     2326
Name: 18, dtype: object
time taken with 4 slaves (MPI execution): 21.27 second(s)
Worker 4 is assigned chunk info [None, 4733904] ../../Combined_Flights_2021.csv
Worker slave 4 is done. Sending back to master
root@f36a2b313128:/T2_files/implementation/Q1# mpiexec -n 6 -machinefile ~/machinefile python -m mpi4py
T3.py
Worker 1 is assigned chunk info [1262374, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
Worker 2 is assigned chunk info [1262375, 1262375] ../../Combined_Flights_2021.csv
Worker slave 2 is done. Sending back to master
Worker 4 is assigned chunk info [1262375, 3787125] ../../Combined_Flights_2021.csv
Worker slave 4 is done. Sending back to master
Worker 5 is assigned chunk info [None, 5049500] ../../Combined_Flights_2021.csv
Worker slave 5 is done. Sending back to master
received from Worker slave 1
received from Worker slave 2
received from Worker slave 3
received from Worker slave 4
received from Worker slave 5
                                          0     1
0                     American Airlines Inc.   759
1                      United Air Lines Inc.   633
2                            JetBlue Airways   487
3    GoJet Airlines, LLC d/b/a United Express   428
4                          Spirit Air Lines   316
5                       SkyWest Airlines Inc.   297
6                        Delta Air Lines Inc.   295
7                Air Wisconsin Airlines Corp   271
8                                 Comair Inc.   202
9   Commutair Aka Champlain Enterprises, Inc.   202
10                                 Envoy Air   135
11               Capital Cargo International   132
12                      Alaska Airlines Inc.   127
13                         Endeavor Air Inc.    80
14                    Frontier Airlines Inc.    79
15                             Allegiant Air    50
16                               Horizon Air    42
17                    Hawaiian Airlines Inc.    36
0                     Southwest Airlines Co.  2326
1                          Republic Airlines   704
2                         Mesa Airlines Inc.   160
3                Air Wisconsin Airlines Corp    15
0    Southwest Airlines Co.
1                     2326
Name: 18, dtype: object
time taken with 5 slaves (MPI execution): 19.54 second(s)
Worker 3 is assigned chunk info [1262375, 2524750] ../../Combined_Flights_2021.csv
Worker slave 3 is done. Sending back to master
```

number of containers	2	3	4	5	6
Time Taken	42.55	34.3	21.48	21.27	19.54

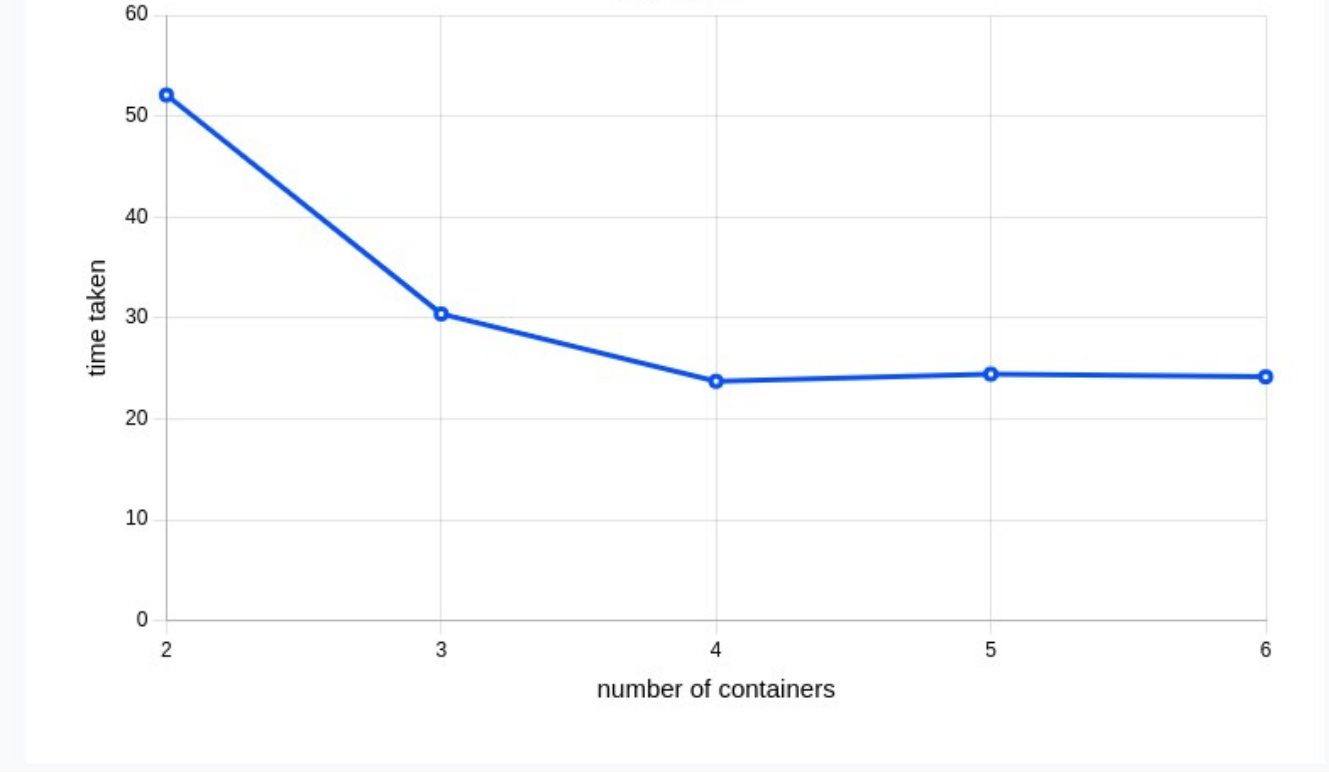


Question 2

```
root@f36a2b313128:/T2_files/implementation/Q2# mpiexec -n 2 -machinefile ~/machinefile python -m mpi4py
T3.py
received from Worker slave 1
263
time taken with 1 slaves (MPI execution): 52.09 second(s)
Worker 1 is assigned chunk info [6311870, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
root@f36a2b313128:/T2_files/implementation/Q2# mpiexec -n 3 -machinefile ~/machinefile python -m mpi4py
T3.py
Worker 1 is assigned chunk info [3155935, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
received from Worker slave 1
received from Worker slave 2
263
time taken with 2 slaves (MPI execution): 30.39 second(s)
Worker 2 is assigned chunk info [None, 3155936] ../../Combined_Flights_2021.csv
Worker slave 2 is done. Sending back to master
root@f36a2b313128:/T2_files/implementation/Q2# mpiexec -n 4 -machinefile ~/machinefile python -m mpi4py
T3.py
Worker 1 is assigned chunk info [2103956, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
Worker 2 is assigned chunk info [2103957, 2103957] ../../Combined_Flights_2021.csv
Worker slave 2 is done. Sending back to master
received from Worker slave 1
received from Worker slave 2
received from Worker slave 3
263
time taken with 3 slaves (MPI execution): 23.72 second(s)
Worker 3 is assigned chunk info [None, 4207914] ../../Combined_Flights_2021.csv
```

```
Worker slave 3 is done. Sending back to master
root@f36a2b313128:/T2_files/implementation/Q2# mpiexec -n 5 -machinefile ~/machinefile python -m mpi4py
T3.py
Worker 1 is assigned chunk info [1577967, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
Worker 2 is assigned chunk info [1577968, 1577968] ../../Combined_Flights_2021.csv
Worker slave 2 is done. Sending back to master
Worker 4 is assigned chunk info [None, 4733904] ../../Combined_Flights_2021.csv
Worker slave 4 is done. Sending back to master
received from Worker slave 1
received from Worker slave 2
received from Worker slave 3
received from Worker slave 4
263
time taken with 4 slaves (MPI execution): 24.43 second(s)
Worker 3 is assigned chunk info [1577968, 3155936] ../../Combined_Flights_2021.csv
Worker slave 3 is done. Sending back to master
root@f36a2b313128:/T2_files/implementation/Q2# mpiexec -n 6 -machinefile ~/machinefile python -m mpi4py
T3.py
Worker 1 is assigned chunk info [1262374, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
Worker 2 is assigned chunk info [1262375, 1262375] ../../Combined_Flights_2021.csv
Worker slave 2 is done. Sending back to master
Worker 3 is assigned chunk info [1262375, 2524750] ../../Combined_Flights_2021.csv
Worker slave 3 is done. Sending back to master
Worker 4 is assigned chunk info [1262375, 3787125] ../../Combined_Flights_2021.csv
Worker slave 4 is done. Sending back to master
received from Worker slave 1
received from Worker slave 2
received from Worker slave 3
received from Worker slave 4
received from Worker slave 5
263
time taken with 5 slaves (MPI execution): 24.16 second(s)
Worker 5 is assigned chunk info [None, 5049500] ../../Combined_Flights_2021.csv
Worker slave 5 is done. Sending back to master
```

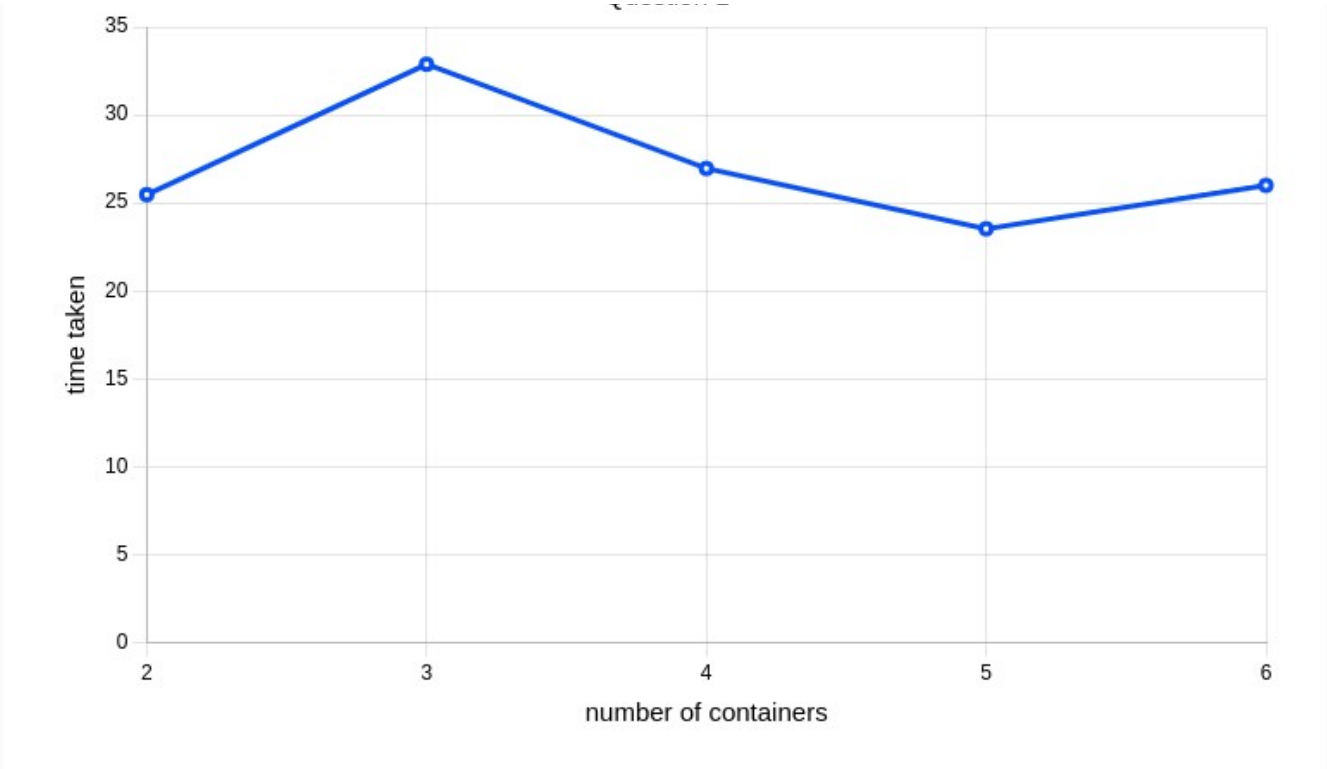
number of containers	2	3	4	5	6
Time Taken	52.09	30.39	23.72	24.43	24.16



Question 3

```
root@f36a2b313128:/T2_files/implementation/Q2# cd ../Q3/
root@f36a2b313128:/T2_files/implementation/Q3# mpiexec -n 2 -machinefile ~/machinefile python -m mpi4py
T3.py
received from Worker slave 1
72.51327755547472
time taken with 1 slaves (MPI execution): 25.47 second(s)
Worker 1 is assigned chunk info [3155934, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
root@f36a2b313128:/T2_files/implementation/Q3# mpiexec -n 3 -machinefile ~/machinefile python -m mpi4py
T3.py
Worker 1 is assigned chunk info [2103955, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
received from Worker slave 1
received from Worker slave 2
72.73409801876956
time taken with 2 slaves (MPI execution): 32.88 second(s)
Worker 2 is assigned chunk info [None, 2103956] ../../Combined_Flights_2021.csv
Worker slave 2 is done. Sending back to master
root@f36a2b313128:/T2_files/implementation/Q3# mpiexec -n 4 -machinefile ~/machinefile python -m mpi4py
T3.py
Worker 1 is assigned chunk info [1577966, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
Worker 2 is assigned chunk info [1577967, 1577967] ../../Combined_Flights_2021.csv
Worker slave 2 is done. Sending back to master
received from Worker slave 1
received from Worker slave 2
received from Worker slave 3
72.73409801876956
time taken with 3 slaves (MPI execution): 26.96 second(s)
Worker 3 is assigned chunk info [None, 3155934] ../../Combined_Flights_2021.csv
Worker slave 3 is done. Sending back to master
root@f36a2b313128:/T2_files/implementation/Q3# mpiexec -n 5 -machinefile ~/machinefile python -m mpi4py
T3.py
Worker 2 is assigned chunk info [1262374, 1262374] ../../Combined_Flights_2021.csv
Worker slave 2 is done. Sending back to master
Worker 3 is assigned chunk info [1262374, 2524748] ../../Combined_Flights_2021.csv
Worker slave 3 is done. Sending back to master
Worker 1 is assigned chunk info [1262373, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
received from Worker slave 1
received from Worker slave 2
received from Worker slave 3
received from Worker slave 4
72.73409801876956
time taken with 4 slaves (MPI execution): 23.53 second(s)
Worker 4 is assigned chunk info [None, 3787122] ../../Combined_Flights_2021.csv
Worker slave 4 is done. Sending back to master
root@f36a2b313128:/T2_files/implementation/Q3# mpiexec -n 6 -machinefile ~/machinefile python -m mpi4py
T3.py
Worker 1 is assigned chunk info [1051977, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
Worker 4 is assigned chunk info [1051978, 3155934] ../../Combined_Flights_2021.csv
Worker slave 4 is done. Sending back to master
Worker 2 is assigned chunk info [1051978, 1051978] ../../Combined_Flights_2021.csv
Worker slave 2 is done. Sending back to master
Worker 3 is assigned chunk info [1051978, 2103956] ../../Combined_Flights_2021.csv
Worker slave 3 is done. Sending back to master
received from Worker slave 1
received from Worker slave 2
received from Worker slave 3
received from Worker slave 4
received from Worker slave 5
72.73409801876956
time taken with 5 slaves (MPI execution): 26.0 second(s)
Worker 5 is assigned chunk info [None, 4207912] ../../Combined_Flights_2021.csv
Worker slave 5 is done. Sending back to master
```

number of containers	2	3	4	5	6
Time Taken	25.47	32.88	26.96	23.53	26.0

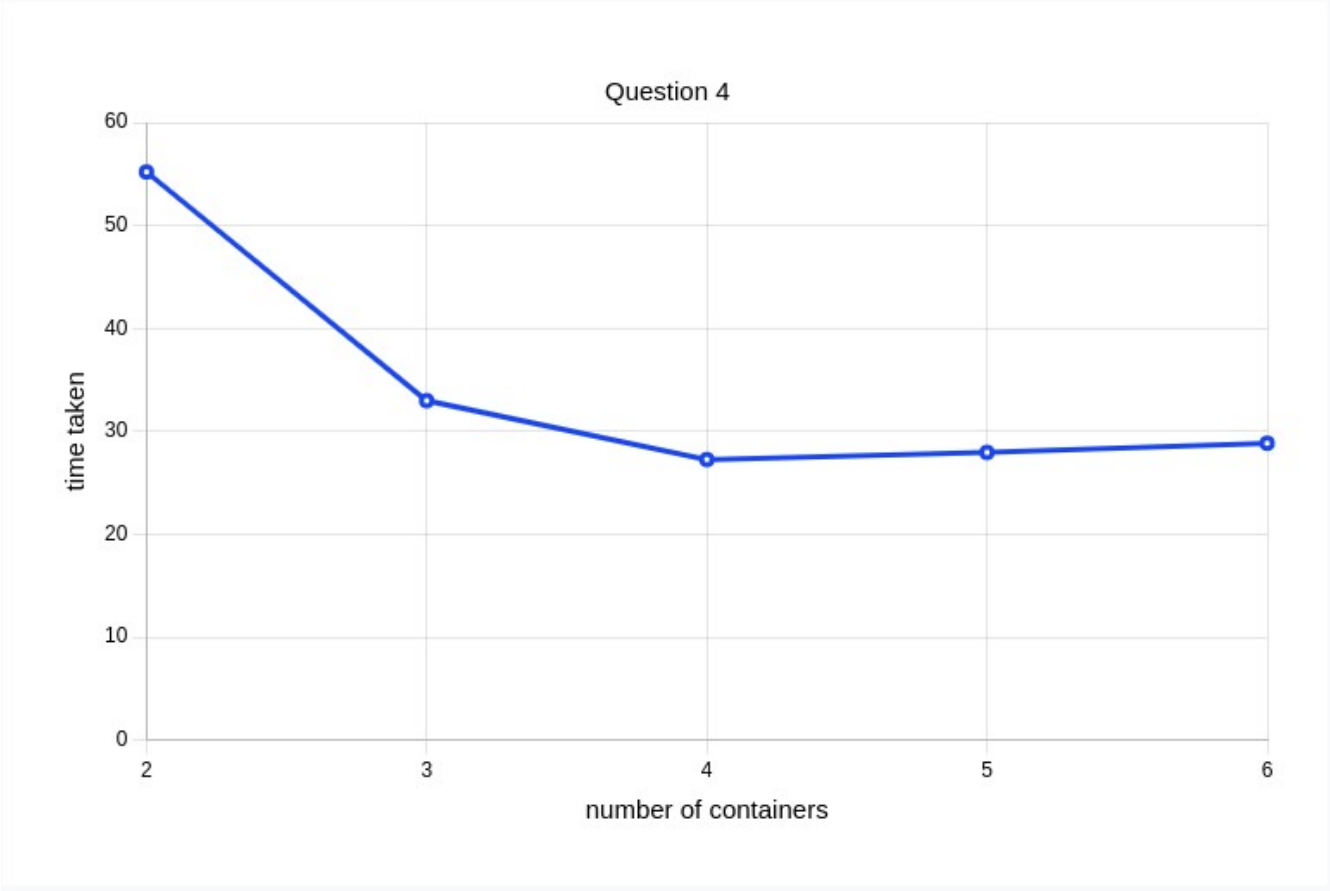


Question 4

```
root@f36a2b313128:/T2_files/implementation/Q4# mpiexec -n 2 -machinefile ~/machinefile python -m mpi4py
T3.py
Worker 1 is assigned chunk info [6311870, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
received from Worker slave 1
365
time taken with 1 slaves (MPI execution): 55.2 second(s)
root@f36a2b313128:/T2_files/implementation/Q4# mpiexec -n 3 -machinefile ~/machinefile python -m mpi4py
T3.py
Worker 1 is assigned chunk info [3155935, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
Worker 2 is assigned chunk info [None, 3155936] ../../Combined_Flights_2021.csv
Worker slave 2 is done. Sending back to master
received from Worker slave 1
received from Worker slave 2
365
time taken with 2 slaves (MPI execution): 32.98 second(s)
root@f36a2b313128:/T2_files/implementation/Q4# mpiexec -n 4 -machinefile ~/machinefile python -m mpi4py
T3.py
Worker 1 is assigned chunk info [2103956, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
Worker 2 is assigned chunk info [2103957, 2103957] ../../Combined_Flights_2021.csv
Worker slave 2 is done. Sending back to master
Worker 3 is assigned chunk info [None, 4207914] ../../Combined_Flights_2021.csv
Worker slave 3 is done. Sending back to master
received from Worker slave 1
received from Worker slave 2
received from Worker slave 3
365
```

```
time taken with 3 slaves (MPI execution): 27.26 second(s)
root@f36a2b313128:/T2_files/implementation/Q4# mpiexec -n 5 -machinefile ~/machinefile python -m mpi4py
T3.py
Worker 1 is assigned chunk info [1577967, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
Worker 2 is assigned chunk info [1577968, 1577968] ../../Combined_Flights_2021.csv
Worker slave 2 is done. Sending back to master
Worker 3 is assigned chunk info [1577968, 3155936] ../../Combined_Flights_2021.csv
Worker slave 3 is done. Sending back to master
Worker 4 is assigned chunk info [None, 4733904] ../../Combined_Flights_2021.csv
Worker slave 4 is done. Sending back to master
received from Worker slave 1
received from Worker slave 2
received from Worker slave 3
received from Worker slave 4
365
time taken with 4 slaves (MPI execution): 27.95 second(s)
root@f36a2b313128:/T2_files/implementation/Q4# mpiexec -n 6 -machinefile ~/machinefile python -m mpi4py
T3.py
Worker 1 is assigned chunk info [1262374, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
Worker 2 is assigned chunk info [1262375, 1262375] ../../Combined_Flights_2021.csv
Worker slave 2 is done. Sending back to master
Worker 3 is assigned chunk info [1262375, 2524750] ../../Combined_Flights_2021.csv
Worker slave 3 is done. Sending back to master
Worker 4 is assigned chunk info [1262375, 3787125] ../../Combined_Flights_2021.csv
Worker slave 4 is done. Sending back to master
Worker 5 is assigned chunk info [None, 5049500] ../../Combined_Flights_2021.csv
Worker slave 5 is done. Sending back to master
received from Worker slave 1
received from Worker slave 2
received from Worker slave 3
received from Worker slave 4
received from Worker slave 5
365
time taken with 5 slaves (MPI execution): 28.84 second(s)
```

number of containers	2	3	4	5	6
Time Taken	55.2	32.98	27.26	27.95	28.84


Question 4
60
50
40
30
20
10
0
time taken
2
3
4
5
6
number of containers

Analysis

This shows that when there is an increase in the number of slaves the time taken decreases and there will be a value of the worker where the value will be the minimum. The decrease in the time taken is logarithmic and there comes a certain number of slaves where the decrease in time is almost constant.

Amdahl's law can be formulated in the following way:[3]

$$S_{\text{latency}}(s) = \frac{1}{(1-p) + \frac{p}{s}}$$

where

- S_{latency} is the theoretical speedup of the execution of the whole task;
- s is the speedup of the part of the task that benefits from improved system resources;
- p is the proportion of execution time that the part benefiting from improved resources originally occupied.

Furthermore,

$$\begin{cases} S_{\text{latency}}(s) \leq \frac{1}{1-p} \\ \lim_{s \to \infty} S_{\text{latency}}(s) = \frac{1}{1-p}. \end{cases}$$

shows that the theoretical speedup of the execution of the whole task increases with the improvement of the resources of the system and that regardless of the magnitude of the improvement, the theoretical speedup is always limited by the part of the task that cannot benefit from the improvement.

Amdahl's law applies only to the cases where the problem size is fixed. In practice, as more computing resources become available, they tend to get used on larger problems (larger datasets), and the time spent in the parallelizable part often grows much faster than the inherently serial work. In this case, Gustafson's law gives a less pessimistic and more realistic assessment of the parallel performance.[4]