

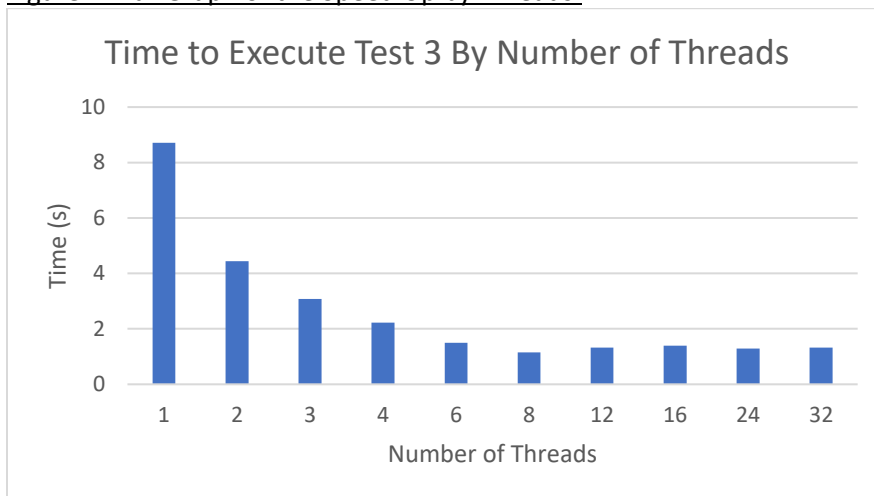
Question 2: Thread Performance

The Table and Graph are as below:

Table 1: Number of threads and Time to Execute.

Number of Threads	Time (s)
1 (Original)	8.730
1	8.712
2	4.445
3	3.083
4	2.23
6	1.503
8	1.156
12	1.319
16	1.393
24	1.295
32	1.321

Figure 1: Bar Graph of the Speed Up by Threads.



- a. N-times speedup:
 - a. Based off the results above, we do see an N-times speed up, until we hit 8 threads, after which we no longer see any speedup. Instead, it continues to take roughly the same amount of time as with 8 threads.
- b. Why no more speedup?
 - a. Based off discussion in class, the most likely reason for a lack of speed up after 8 threads is because the system this program is being run on (the CPSC servers) only lets us use 8 cores/cpus (or the system itself only has 8 cores/cpus). After 8 threads, it is being forced to simulate multithreading, which doesn't actually provide any speedup, since we still only have 8 cores running at full throttle.

For raw data, see the Appendix.

Appendix:

Question 2:

The raw timing results are as follows: (note: I had my debug printing off. This has since been turned off, with no significant differences).

```
john.ngo@csx:~/457/A2/subset-sum-master$ time ./subsetOrig
3 < test3.txt

Sorry, I don't know how to use multiple threads yet.
Using 1 thread(s) on 27 numbers.
134217728
Subsets found: 557424

real    0m8.730s
user    0m8.661s
sys     0m0.003s
john.ngo@csx:~/457/A2/subset-sum-master$

john.ngo@csx:~/457/A2/subset-sum-master$ time ./subset 1 <
test3.txt

Using 1 thread(s) on 27 numbers.
Number Zeros Counted by Thread: 557424
Subsets found: 557424

real    0m8.712s
user    0m8.662s
sys     0m0.002s

john.ngo@csx:~/457/A2/subset-sum-master$ time ./subset 2 <
test3.txt

Using 2 thread(s) on 27 numbers.
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 557424
Subsets found: 557424

real    0m4.445s
user    0m8.797s
sys     0m0.005s

john.ngo@csx:~/457/A2/subset-sum-master$ time ./subset 3 <
test3.txt

Using 3 thread(s) on 27 numbers.
Number Zeros Counted by Thread: 465587
Number Zeros Counted by Thread: 91837
Number Zeros Counted by Thread: 0
Subsets found: 557424

real    0m3.083s
user    0m8.817s
sys     0m0.002s
```

test3.txt

```
john.ngo@csx:~/457/A2/subset-sum-master$ time ./subset 4 <
```

```
Using 4 thread(s) on 27 numbers.  
Number Zeros Counted by Thread: 338337  
Number Zeros Counted by Thread: 219087  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 0  
Subsets found: 557424
```

```
real  0m2.230s  
user  0m8.757s  
sys   0m0.004s
```

test3.txt

```
john.ngo@csx:~/457/A2/subset-sum-master$ time ./subset 6 <
```

```
Using 6 thread(s) on 27 numbers.  
Number Zeros Counted by Thread: 262244  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 203343  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 91837  
Number Zeros Counted by Thread: 0  
Subsets found: 557424
```

```
real  0m1.503s  
user  0m8.810s  
sys   0m0.004s
```

test3.txt

```
john.ngo@csx:~/457/A2/subset-sum-master$ time ./subset 8 <
```

```
Using 8 thread(s) on 27 numbers.  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 187615  
Number Zeros Counted by Thread: 147915  
Number Zeros Counted by Thread: 150722  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 71172  
Number Zeros Counted by Thread: 0  
Subsets found: 557424
```

```
real  0m1.156s  
user  0m8.835s  
sys   0m0.007s
```

< test3.txt

```
john.ngo@csx:~/457/A2/subset-sum-master$ time ./subset 12
```

```
Using 12 thread(s) on 27 numbers.  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 132102  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 76093  
Number Zeros Counted by Thread: 127250  
Number Zeros Counted by Thread: 21733  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 130142  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 70104  
Subsets found: 557424
```

```
real 0m1.319s  
user 0m9.567s  
sys 0m0.008s
```

< test3.txt

```
john.ngo@csx:~/457/A2/subset-sum-master$ time ./subset 16
```

```
Using 16 thread(s) on 27 numbers.  
Number Zeros Counted by Thread: 94774  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 93846  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 55074  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 17891  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 53281  
Number Zeros Counted by Thread: 92841  
Number Zeros Counted by Thread: 92841  
Number Zeros Counted by Thread: 56876  
Number Zeros Counted by Thread: 0  
Subsets found: 557424
```

```
real 0m1.393s  
user 0m9.479s  
sys 0m0.006s
```

< test3.txt

```
john.ngo@csx:~/457/A2/subset-sum-master$ time ./subset 24
```

```
Using 24 thread(s) on 27 numbers.  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 54604  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 20665  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 74629  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 52785  
Number Zeros Counted by Thread: 3526  
Number Zeros Counted by Thread: 75538  
Number Zeros Counted by Thread: 21808  
Number Zeros Counted by Thread: 57473  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 74465  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 18207  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 54285  
Number Zeros Counted by Thread: 49439  
Subsets found: 557424
```

```
real 0m1.295s  
user 0m9.662s  
sys 0m0.010s
```

```
john.ngo@csx:~/457/A2/subset-sum-master$ time ./subset 32
```

< test3.txt

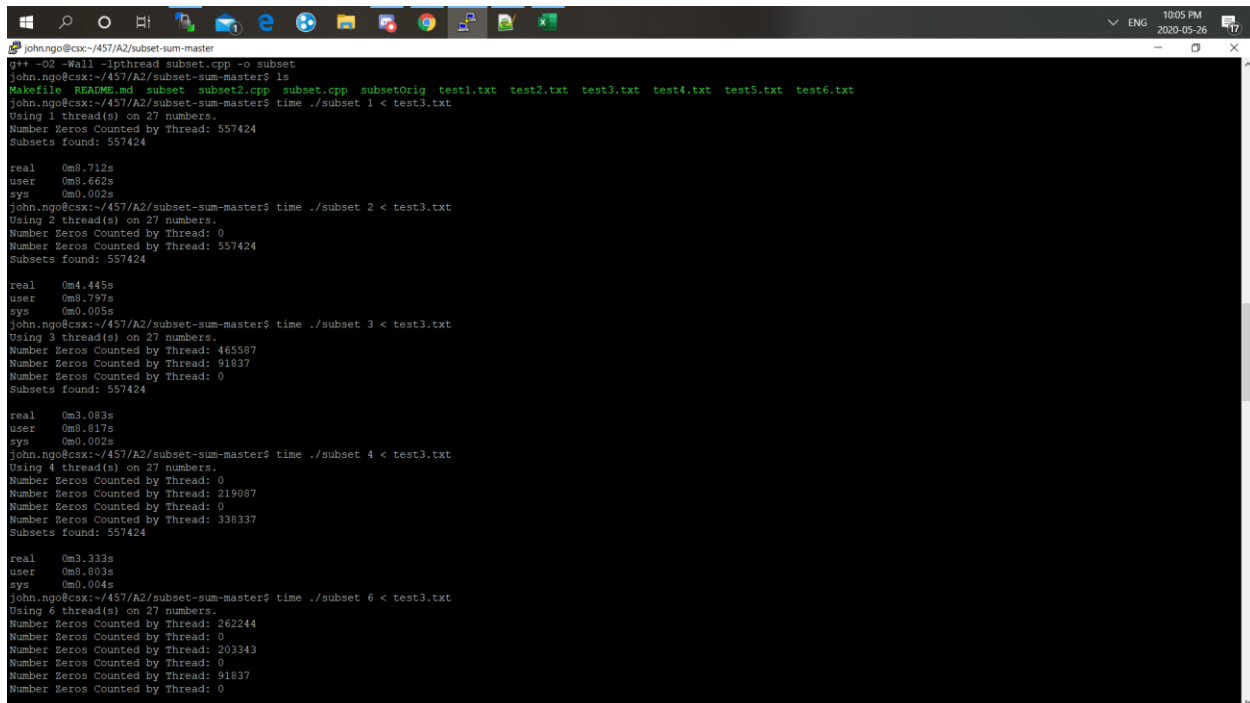
```
Using 32 thread(s) on 27 numbers.  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 14770  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 39674  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 16370  
Number Zeros Counted by Thread: 0  
Number Zeros Counted by Thread: 3121  
Number Zeros Counted by Thread: 40624  
Number Zeros Counted by Thread: 0
```

Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 53167
Number Zeros Counted by Thread: 38704
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 17202
Number Zeros Counted by Thread: 53222
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 37724
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 39674
Number Zeros Counted by Thread: 53167
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 39674
Number Zeros Counted by Thread: 41552
Number Zeros Counted by Thread: 15557
Number Zeros Counted by Thread: 53222
Number Zeros Counted by Thread: 0
Subsets found: 557424

real 0m1.321s
user 0m10.048s
sys 0m0.010s

john.ngo@csx:~/457/A2/subset-sum-master\$

Documentation Screenshots:



```
john.ngo@csx:~/457/A2/subset-sum-master$ g++ -O2 -Wall -lpthread subset.cpp -o subset
john.ngo@csx:~/457/A2/subset-sum-master$ ls
Makefile  README.md  subset  subset2.cpp  subset.cpp  subsetOrig  test1.txt  test2.txt  test3.txt  test4.txt  test5.txt  test6.txt
john.ngo@csx:~/457/A2/subset-sum-master$ time ./subset 1 < test3.txt
Using 1 thread(s) on 27 numbers.
Number Zeros Counted by Thread: 557424
Subsets found: 557424

real    0m8.712s
user    0m8.462s
sys     0m0.002s
john.ngo@csx:~/457/A2/subset-sum-master$ time ./subset 2 < test3.txt
Using 2 thread(s) on 27 numbers.
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 557424
Subsets found: 557424

real    0m4.445s
user    0m8.797s
sys     0m0.005s
john.ngo@csx:~/457/A2/subset-sum-master$ time ./subset 3 < test3.txt
Using 3 thread(s) on 27 numbers.
Number Zeros Counted by Thread: 465587
Number Zeros Counted by Thread: 91837
Number Zeros Counted by Thread: 0
Subsets found: 557424

real    0m3.083s
user    0m8.817s
sys     0m0.002s
john.ngo@csx:~/457/A2/subset-sum-master$ time ./subset 4 < test3.txt
Using 4 thread(s) on 27 numbers.
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 219087
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 338337
Subsets found: 557424

real    0m3.333s
user    0m8.803s
sys     0m0.004s
john.ngo@csx:~/457/A2/subset-sum-master$ time ./subset 6 < test3.txt
Using 6 thread(s) on 27 numbers.
Number Zeros Counted by Thread: 262244
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 203343
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 91837
Number Zeros Counted by Thread: 0
Subsets found: 557424
```

```
johnngo@csc:~/457/A2/subset-sum-master
Number Zeros Counted by Thread: 0
Subsets found: 557424

real    0m1.503s
user    0m0.810s
sys     0m0.004s
johnngo@csc:~/457/A2/subset-sum-master$ time ./subset 8 < test3.txt
Using 8 thread(s) on 27 numbers.
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 187615
Number Zeros Counted by Thread: 147915
Number Zeros Counted by Thread: 150722
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 71172
Number Zeros Counted by Thread: 0
Subsets found: 557424

real    0m1.156s
user    0m0.835s
sys     0m0.007s
johnngo@csc:~/457/A2/subset-sum-master$ ^C
johnngo@csc:~/457/A2/subset-sum-master$ time ./subset 12 < test3.txt
Using 12 thread(s) on 27 numbers.
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 132102
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 76093
Number Zeros Counted by Thread: 127250
Number Zeros Counted by Thread: 21733
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 130142
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 70104
Subsets found: 557424

real    0m1.319s
user    0m0.567s
sys     0m0.008s
johnngo@csc:~/457/A2/subset-sum-master$ time ./subset 16 < test3.txt
Using 16 thread(s) on 27 numbers.
Number Zeros Counted by Thread: 94774
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 93846
```

```

johnngo@csc:~/A2/subset-sum-master
Subsets found: 557424

real    0m1.319s
user    0m9.567s
sys     0m0.008s
johnngo@csc:~/A2/subset-sum-master$ time ./subset 16 < test3.txt
Using 16 thread(s) on 27 numbers.
Number Zeros Counted by Thread: 94774
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 93846
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 55074
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 17891
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 53281
Number Zeros Counted by Thread: 92841
Number Zeros Counted by Thread: 92841
Number Zeros Counted by Thread: 56876
Number Zeros Counted by Thread: 0
Subsets found: 557424

real    0m1.393s
user    0m9.479s
sys     0m0.006s
johnngo@csc:~/A2/subset-sum-master$ ^C
johnngo@csc:~/A2/subset-sum-master$ time ./subset 24 < test3.txt
Using 24 thread(s) on 27 numbers.
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 54604
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 20665
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 74629
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 52785
Number Zeros Counted by Thread: 3526
Number Zeros Counted by Thread: 75538
Number Zeros Counted by Thread: 21808
Number Zeros Counted by Thread: 57473
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 74465
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 19207
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 54285
Number Zeros Counted by Thread: 49439
Subsets found: 557424

real    0m1.295s
user    0m9.662s
sys     0m0.010s
johnngo@csc:~/A2/subset-sum-master$ time ./subset 32 < test3.txt
Using 32 thread(s) on 27 numbers.
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 14770
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 39674
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 16370
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 3121
Number Zeros Counted by Thread: 40624
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 53167
Number Zeros Counted by Thread: 38704
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 17202
Number Zeros Counted by Thread: 53222
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 37724
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 39674
Number Zeros Counted by Thread: 53167
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 39674
Number Zeros Counted by Thread: 41552
Number Zeros Counted by Thread: 15557

```



```
john.ngo@csc:~/A2/subset-sum-master
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 14770
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 39674
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 16370
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Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 53167
Number Zeros Counted by Thread: 38704
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 17202
Number Zeros Counted by Thread: 53222
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 37724
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 39674
Number Zeros Counted by Thread: 53167
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 39674
Number Zeros Counted by Thread: 41552
Number Zeros Counted by Thread: 15557
Number Zeros Counted by Thread: 53222
Number Zeros Counted by Thread: 0
Subsets found: 557424

real    0m1.321s
user    0m10.048s
sys      0m0.010s
john.ngo@csc:~/A2/subset-sum-master$ ^C
john.ngo@csc:~/A2/subset-sum-master$ time ./subset 4 < test3.txt
Using 4 thread(s) on 27 numbers.
Number Zeros Counted by Thread: 338337
Number Zeros Counted by Thread: 219087
Number Zeros Counted by Thread: 0
Number Zeros Counted by Thread: 0
Subsets found: 557424

real    0m2.230s
user    0m8.757s
sys      0m0.004s
john.ngo@csc:~/A2/subset-sum-master$ ^C
john.ngo@csc:~/A2/subset-sum-master$
```