Applied GPU Programming - Assignment 4 - Group 19

Group members and contributions

We did the assignment together and in-person, therefore both of us contributed the same amount of work.

- Diogo Gaspar - dgaspar@kth.se (mailto:dgaspar@kth.se) - 50%
- Diogo Melita - diogogm@kth.se (mailto:diogogm@kth.se) - 50%

Exercise 1

Question 1: X = 800, Y = 600, Grid = 32x16 blocks

Per grid, the number of blocks along, respectively, the horizontal (X) and vertical (Y) axis can be calculated as follows:

- X: $\lceil \frac{800}{32} \rceil = 25$
- Y: $\lceil \frac{600}{16} \rceil = 38$

Furthermore, each block holds 32×16 threads, and since each warp consists of 32 threads, as per the assignment's statement, we have 16 warps per block. As such, the total warps will be $25 \times 38 \times 16 = 15200$.

Now, as for control divergence, we have that $800 \% 32 = 0$, and that $600 \% 16 = 8$, which leads to there being no horizontal divergence, only possibly vertical one – and with vertical divergence of 8. Since wraps are processed sequentially and their size is 32, which is the same size of the X-dimension of the block, each wrap will cointain one line of the block. The last 8 lines do not make part of the grid and thus will be processed wall in the same way leading to having 0 wraps with control divergence.

Question 2: X = 600, Y = 800

Now, in the X-axis, we have $\lceil \frac{600}{32} \rceil = 19$ blocks, and $\lceil \frac{800}{16} \rceil = 50$ in the Y-axis.

The number of total wraps in the grid is $19 \times 50 \times 16 = 15,200$ wraps.

For the control divergence, the remainder in the X-dimension is $600\%32 = 4$ and in the Y-dimension is $800\%16 = 0$.

Each wrap will contain one line of the block as mentioned in the previous question. However, in the last block of the X-dimension, 4 columns will be outside of the grid, thus only some threads will perform computations.

Therefore, the number of wraps without control divergence is $50 \times 16 = 800$ wraps.

Question 3: X = 600, Y = 799

In the X-axis, we have $\lceil \frac{600}{32} \rceil = 19$ blocks, and $\lceil \frac{799}{16} \rceil = 50$ in the Y-axis.

The number of total wraps in the grid is $19 \times 50 \times 16 = 15,200$ wraps.

For the control divergence, the remainder in the X-dimension is $600\%32 = 4$ and in the Y-dimension is $799\%16 = 15$.

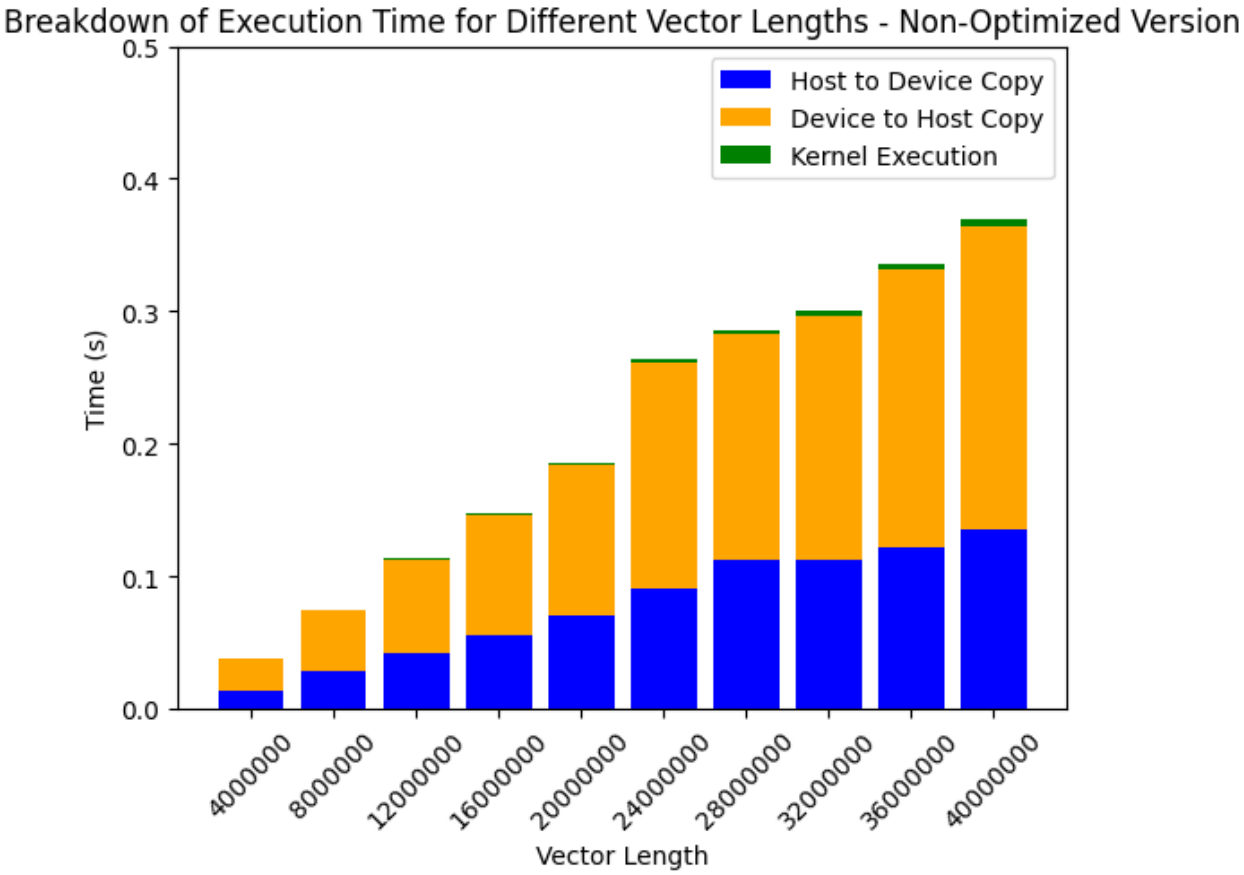
In this case, since there is one less row in the Y-dimension, the last block will contain 15 rows outside of the grid. However, as mentioned previously, each wrap will have one line of the block, thus the last 15 rows will be processed in the same manner. Therefore, there is no divergence control in the Y-dimension.

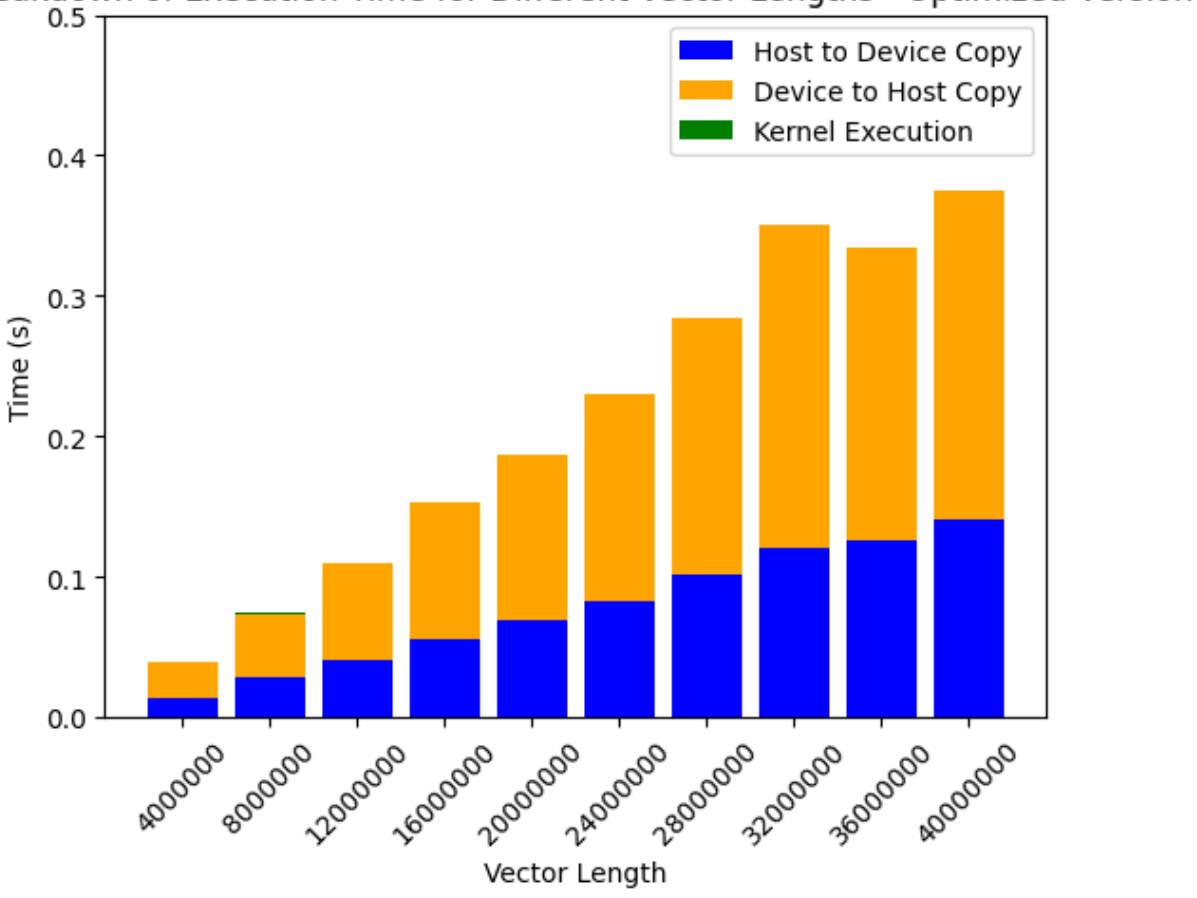
We will then have $50 \times 16 - 1 = 799$ wraps with control divergence. We subtract 1 because since we removed a line from the program, one wrap disappears.

Exercise 2

Question 1

Below you can see both execution time breakdowns for different vector lengths: the first for the non-optimized version, with the second being related to the stream-optimized version.


Breakdown of Execution Time for Different Vector Lengths - Non-Optimized Version
Host to Device Copy
Device to Host Copy
Kernel Execution
Time (s)
0.0
0.1
0.2
0.3
0.4
0.5
4000000
8000000
12000000
16000000
20000000
24000000
28000000
32000000
36000000
40000000
Vector Length


Breakdown of Execution Time for Different Vector Lengths - Optimized Version
Host to Device Copy
Device to Host Copy
Kernel Execution
Time (s)
0.0
0.1
0.2
0.3
0.4
0.5
4000000
8000000
12000000
16000000
20000000
24000000
28000000
32000000
36000000
40000000
Vector Length

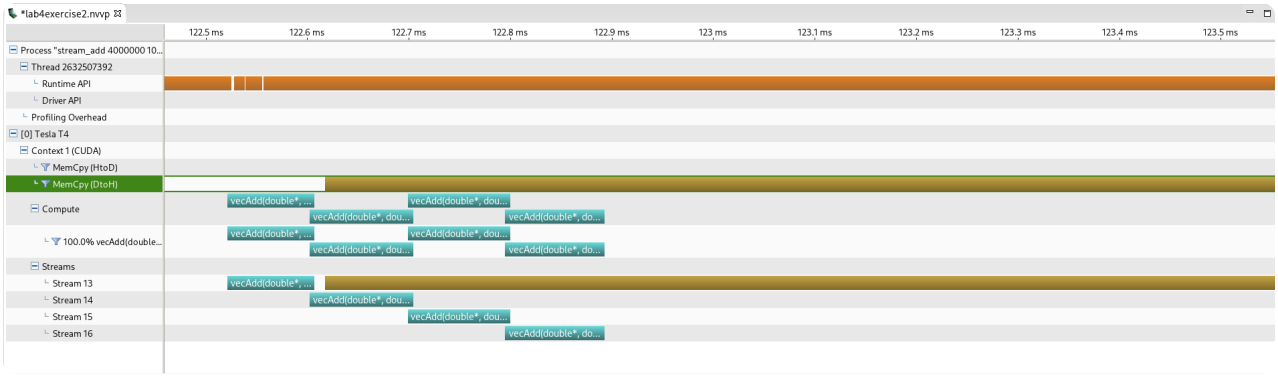
The optimized version seems to have one outlier (we ran the tests several times – these were not deterministic); however, ignoring those, we can see that time seems to linearly grow with increasing vector lengths. Additionally, we also verify that using streams, we reduce the Kernel Execution time to almost zero

Question 2

To trace the performance, we used the following command (note that the vector size was set to 262144):

```
nvprof --output-profile lab4exercise2.nvvp -f ./hw4_ex2 4000000 1000000
```

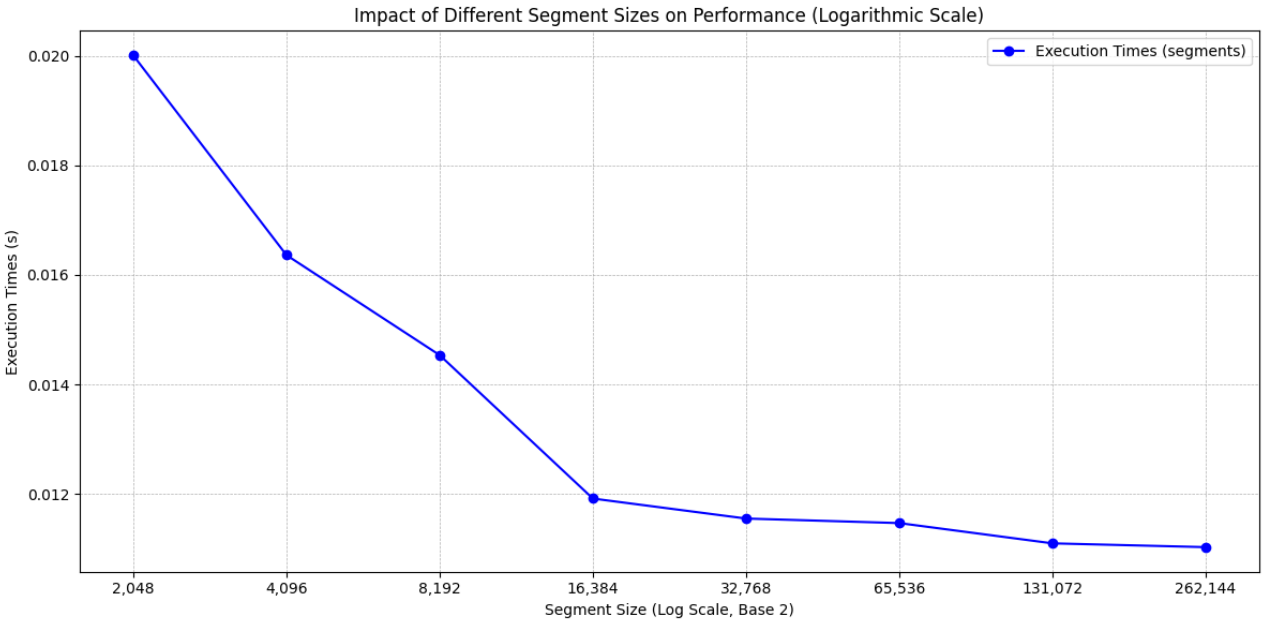
!



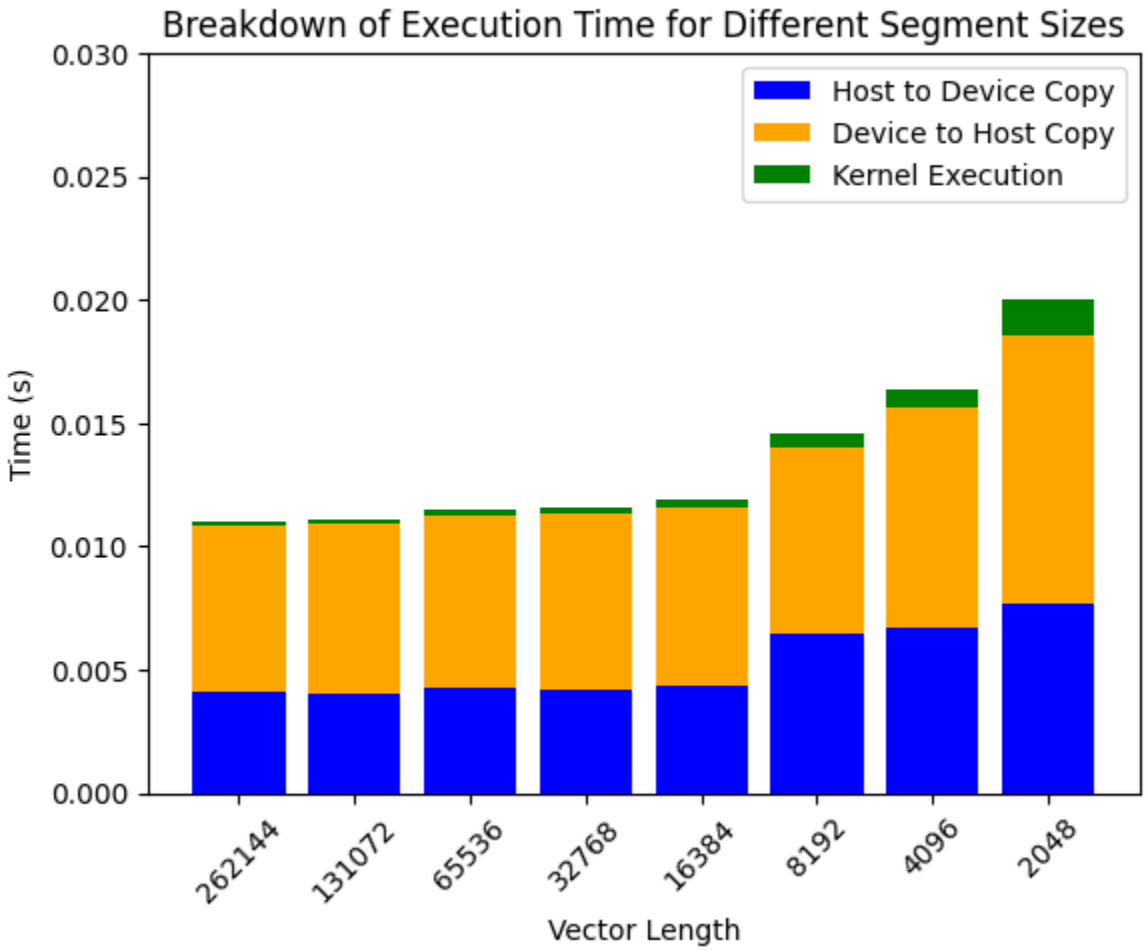
From the timeline, we observe concurrent execution across multiple streams (Streams 13 to 16), which indicates (partial) overlap of communication and computation.

Question 3

We chose to run this experiment with an input size of 2^{20} which is 1048576, and segment sizes between 2^{11} to 2^{18}. This output leads us to conclude that the segment size impacts on performance with bigger segment sizes leading to lower total execution times.



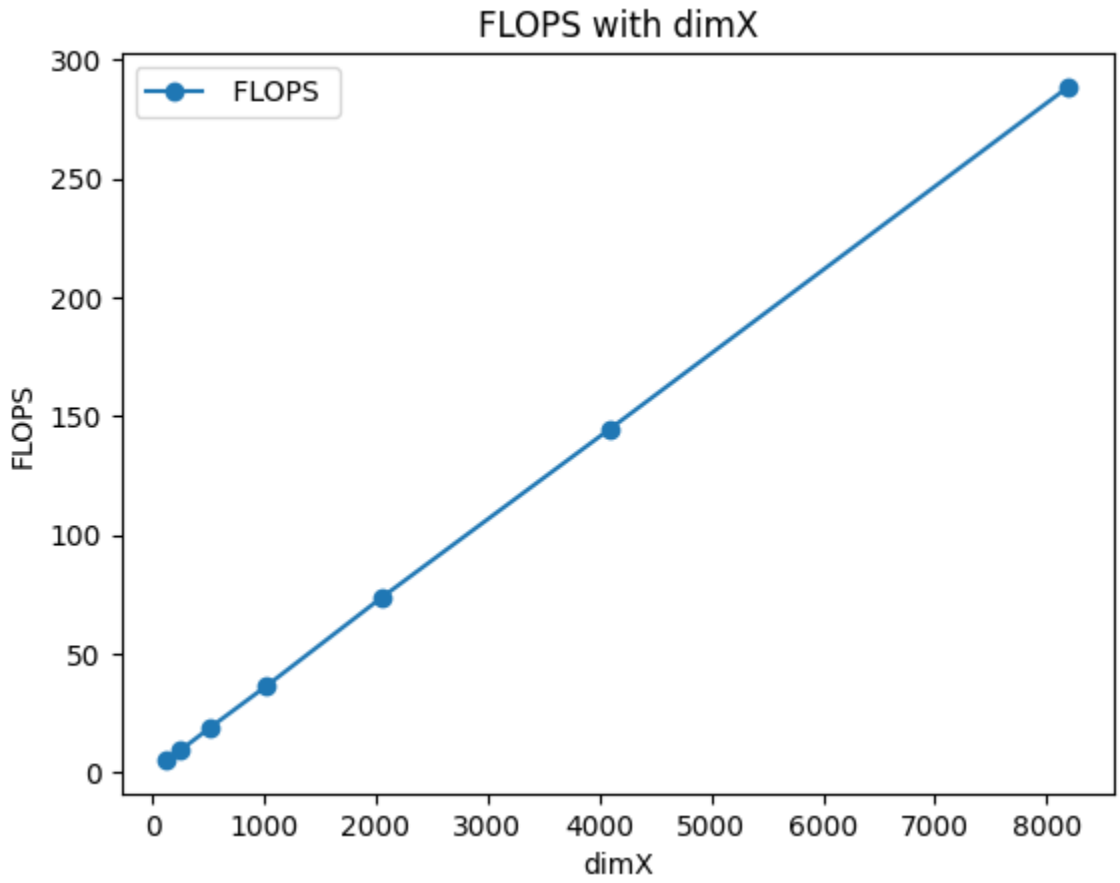
We can also see that smaller segment sizes lead to more time spent in copying from device to host and to bigger kernel execution times, as expected.



Exercise 3

Question 1

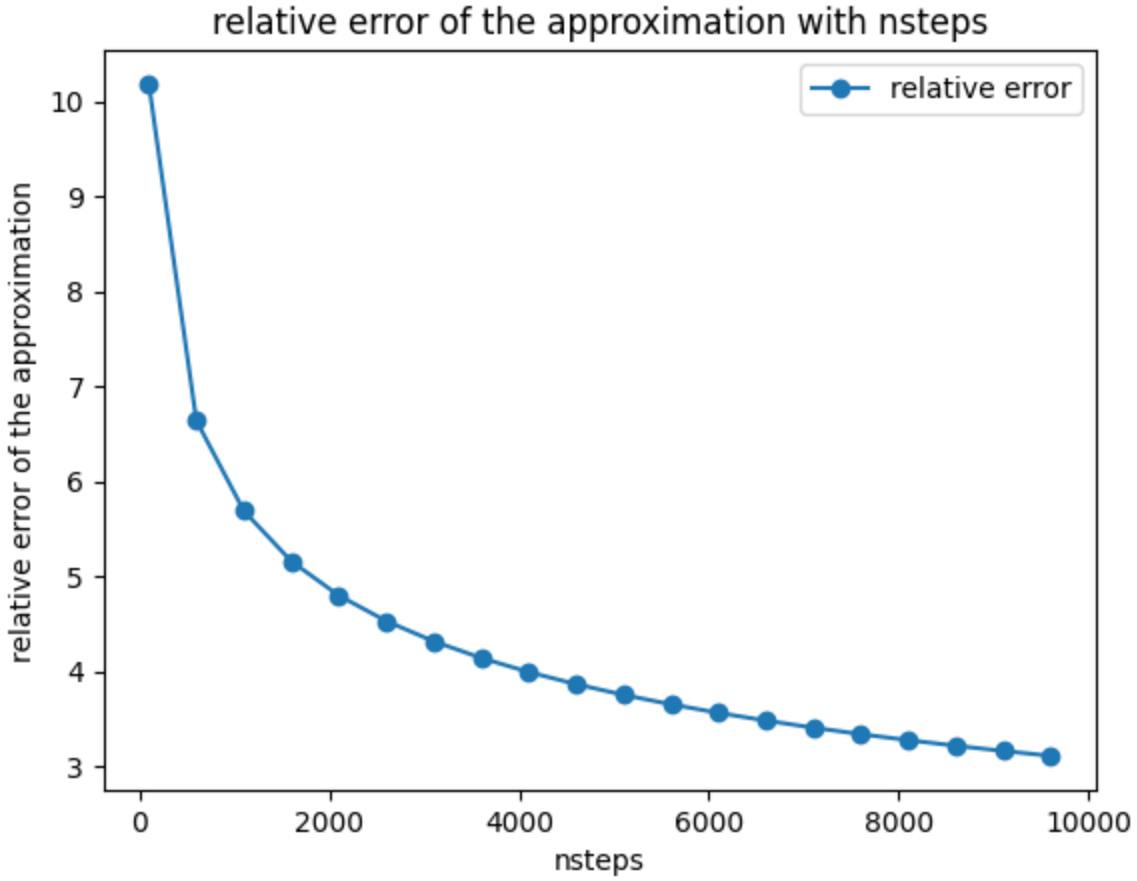
We fixed the step at 100, and continuosly increased the step by doubling it, from 128 to 12800 (not inclusive).



From the plot, we noticed that the amount of floating point operations is basically linearly related to the increase of input data.

Question 2

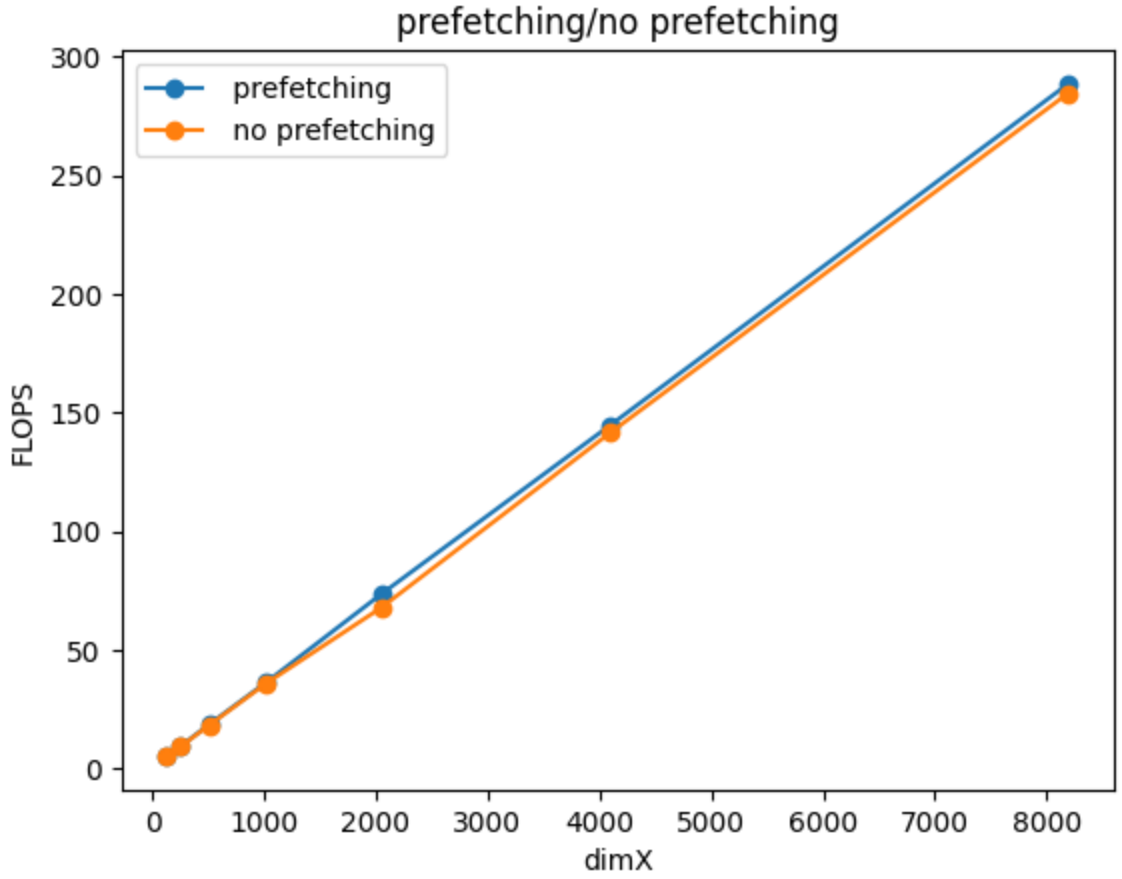
We fixed, as mentioned in the question's statement, dimX at 1024, and the steps range from 100 to 10000, increasing by 500.

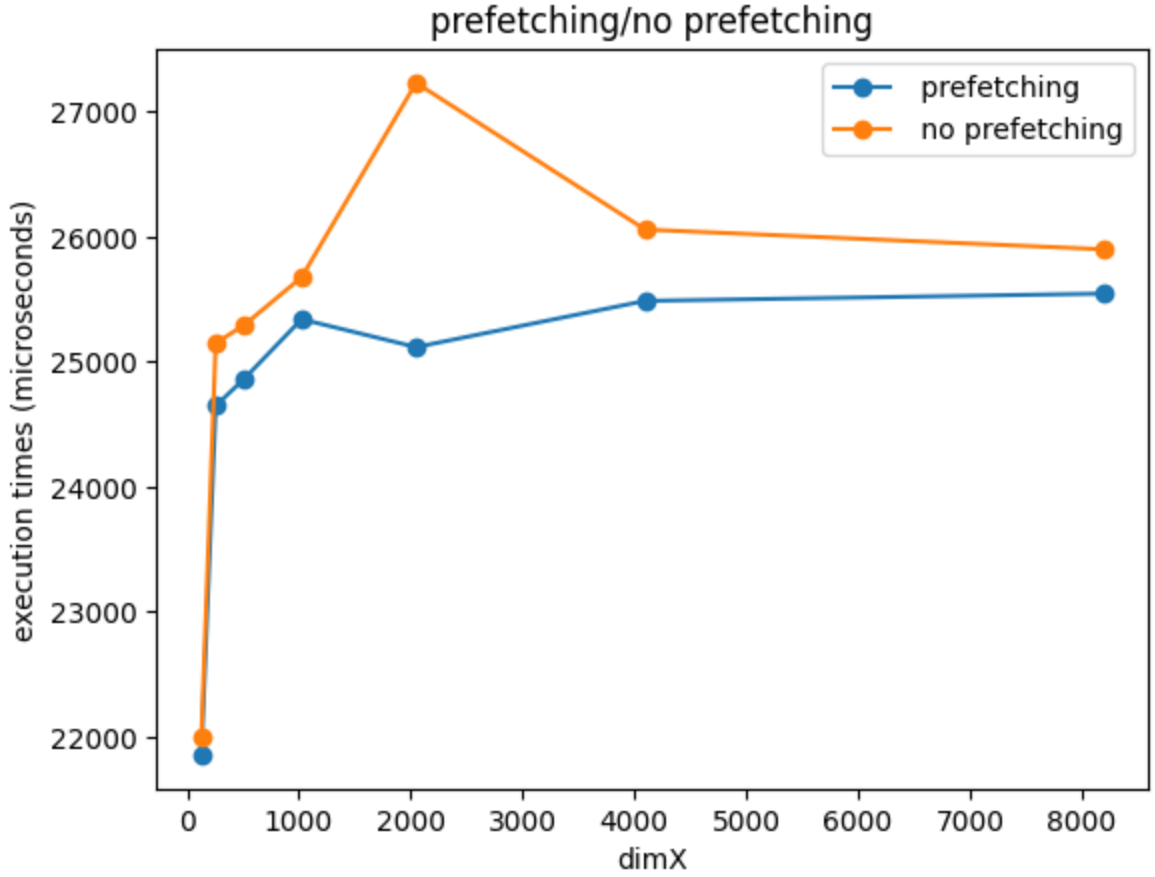


From the figure, we can find that the relative error decreases exponentially as the number of iterations increases.

Question 3

We plotted two plots for this question: one comparing FLOPS, and one comparing execution time, for each configuration (with and without prefetching):


prefetching/no prefetching
prefetching
no prefetching
FLOPS
dimX
0
50
100
150
200
250
300
0
1000
2000
3000
4000
5000
6000
7000
8000


prefetching/no prefetching
prefetching
no prefetching
execution times (microseconds)
dimX
22000
23000
24000
25000
26000
27000
0
1000
2000
3000
4000
5000
6000
7000
8000

As we can see, the amount of FLOPS is kept more-or-less similar with increasing dimX values; however, the execution time decreases a lot with prefetching, as expected!