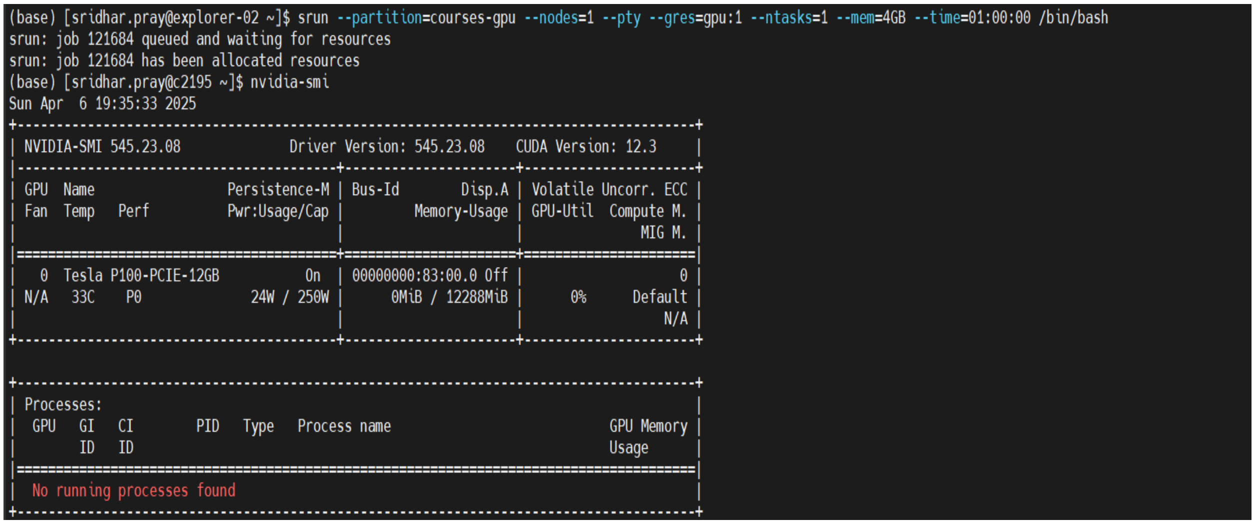
Question – 4

Assignment - 5

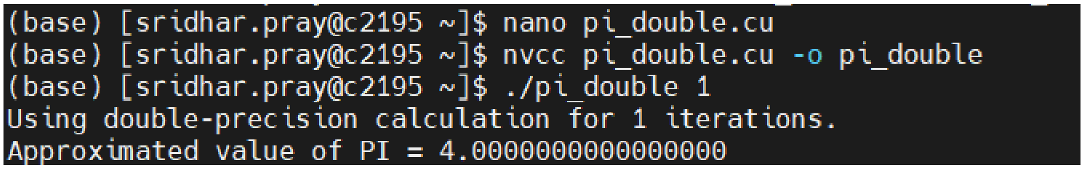
Let’s revisit computing the value of pi, but this time we will use a series. For instance, we provide you with code for the Leibniz’s series, developed by Jose Cintra. Implement this series on the GPU, allowing the user to enter the number of iterations. Make sure to develop an efficient computation of this kernel that utilizes the parallelism provided on the GPU. Then modify this code to use single precision math. Show results for at least 10 different number of iterations of the series and discuss how precision plays a role in the rate of convergence.

Answer:



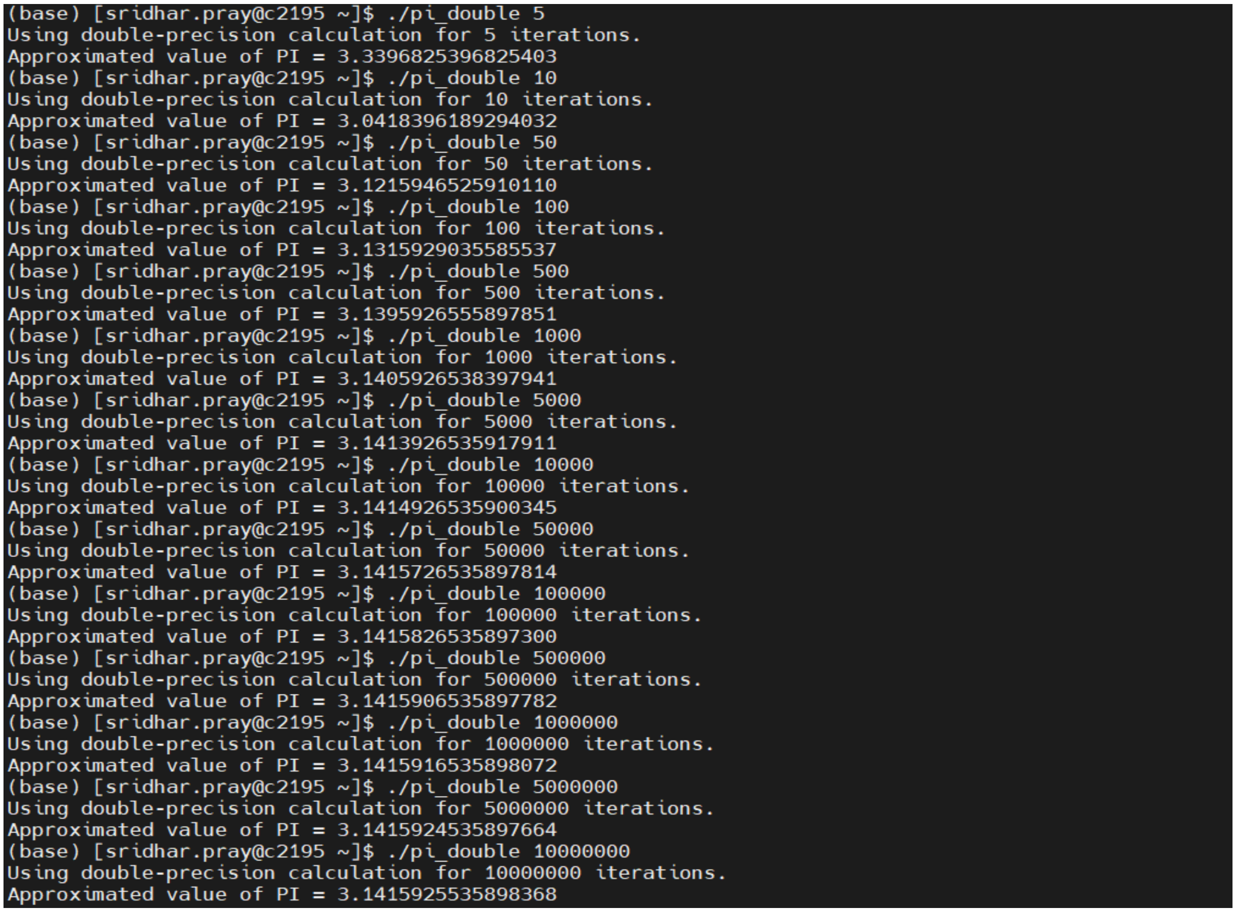
```
(base) [sridhar.pray@explorer-02 ~]$ srun --partition=courses-gpu --nodes=1 --pty --gres=gpu:1 --ntasks=1 --mem=4GB --time=01:00:00 /bin/bash
srun: job 121684 queued and waiting for resources
srun: job 121684 has been allocated resources
(base) [sridhar.pray@c2195 ~]$ nvidia-smi
Sun Apr  6 19:35:33 2025
+---------------------------------------------------------------------------------------+
| NVIDIA-SMI 545.23.08              Driver Version: 545.23.08    CUDA Version: 12.3     |
|-----------------------------------------+----------------------+----------------------+
| GPU  Name                 Persistence-M | Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf          Pwr:Usage/Cap |         Memory-Usage | GPU-Util  Compute M. |
|                                         |                      |               MIG M. |
|=========================================+======================+======================|
|   0  Tesla P100-PCIE-12GB           On  | 00000000:83:00.0 Off |                    0 |
| N/A   33C    P0              24W / 250W |      0MiB / 12288MiB |      0%      Default |
|                                         |                      |                  N/A |
+-----------------------------------------+----------------------+----------------------+

+---------------------------------------------------------------------------------------+
| Processes:                                                                            |
|  GPU   GI   CI        PID   Type   Process name                            GPU Memory |
|        ID   ID                                                             Usage      |
|=======================================================================================|
|  No running processes found                                                           |
+---------------------------------------------------------------------------------------+
```

This is the output for 1 iteration in double precision:

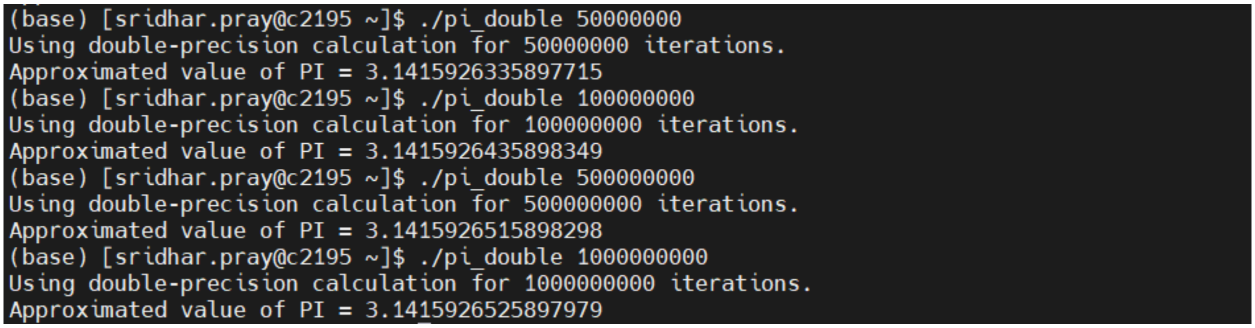


```
(base) [sridhar.pray@c2195 ~]$ nano pi_double.cu
(base) [sridhar.pray@c2195 ~]$ nvcc pi_double.cu -o pi_double
(base) [sridhar.pray@c2195 ~]$ ./pi_double 1
Using double-precision calculation for 1 iterations.
Approximated value of PI = 4.0000000000000000
```

This is the output for 10 different number of iterations:

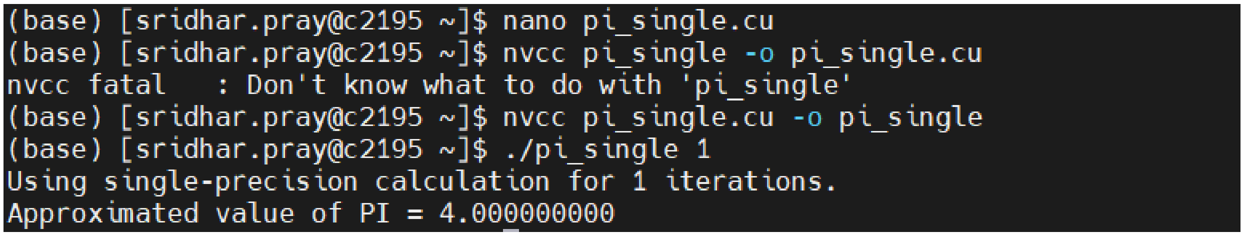


```
(base) [sridhar.pray@c2195 ~]$ ./pi_double 5
Using double-precision calculation for 5 iterations.
Approximated value of PI = 3.3396825396825403
(base) [sridhar.pray@c2195 ~]$ ./pi_double 10
Using double-precision calculation for 10 iterations.
Approximated value of PI = 3.0418396189294032
(base) [sridhar.pray@c2195 ~]$ ./pi_double 50
Using double-precision calculation for 50 iterations.
Approximated value of PI = 3.1215946525910110
(base) [sridhar.pray@c2195 ~]$ ./pi_double 100
Using double-precision calculation for 100 iterations.
Approximated value of PI = 3.1315929035585537
(base) [sridhar.pray@c2195 ~]$ ./pi_double 500
Using double-precision calculation for 500 iterations.
Approximated value of PI = 3.1395926555897851
(base) [sridhar.pray@c2195 ~]$ ./pi_double 1000
Using double-precision calculation for 1000 iterations.
Approximated value of PI = 3.1405926538397941
(base) [sridhar.pray@c2195 ~]$ ./pi_double 5000
Using double-precision calculation for 5000 iterations.
Approximated value of PI = 3.1413926535917911
(base) [sridhar.pray@c2195 ~]$ ./pi_double 10000
Using double-precision calculation for 10000 iterations.
Approximated value of PI = 3.1414926535900345
(base) [sridhar.pray@c2195 ~]$ ./pi_double 50000
Using double-precision calculation for 50000 iterations.
Approximated value of PI = 3.1415726535897814
(base) [sridhar.pray@c2195 ~]$ ./pi_double 100000
Using double-precision calculation for 100000 iterations.
Approximated value of PI = 3.1415826535897300
(base) [sridhar.pray@c2195 ~]$ ./pi_double 500000
Using double-precision calculation for 500000 iterations.
Approximated value of PI = 3.1415906535897782
(base) [sridhar.pray@c2195 ~]$ ./pi_double 1000000
Using double-precision calculation for 1000000 iterations.
Approximated value of PI = 3.1415916535898072
(base) [sridhar.pray@c2195 ~]$ ./pi_double 5000000
Using double-precision calculation for 5000000 iterations.
Approximated value of PI = 3.1415924535897664
(base) [sridhar.pray@c2195 ~]$ ./pi_double 10000000
Using double-precision calculation for 10000000 iterations.
Approximated value of PI = 3.1415925535898368
```



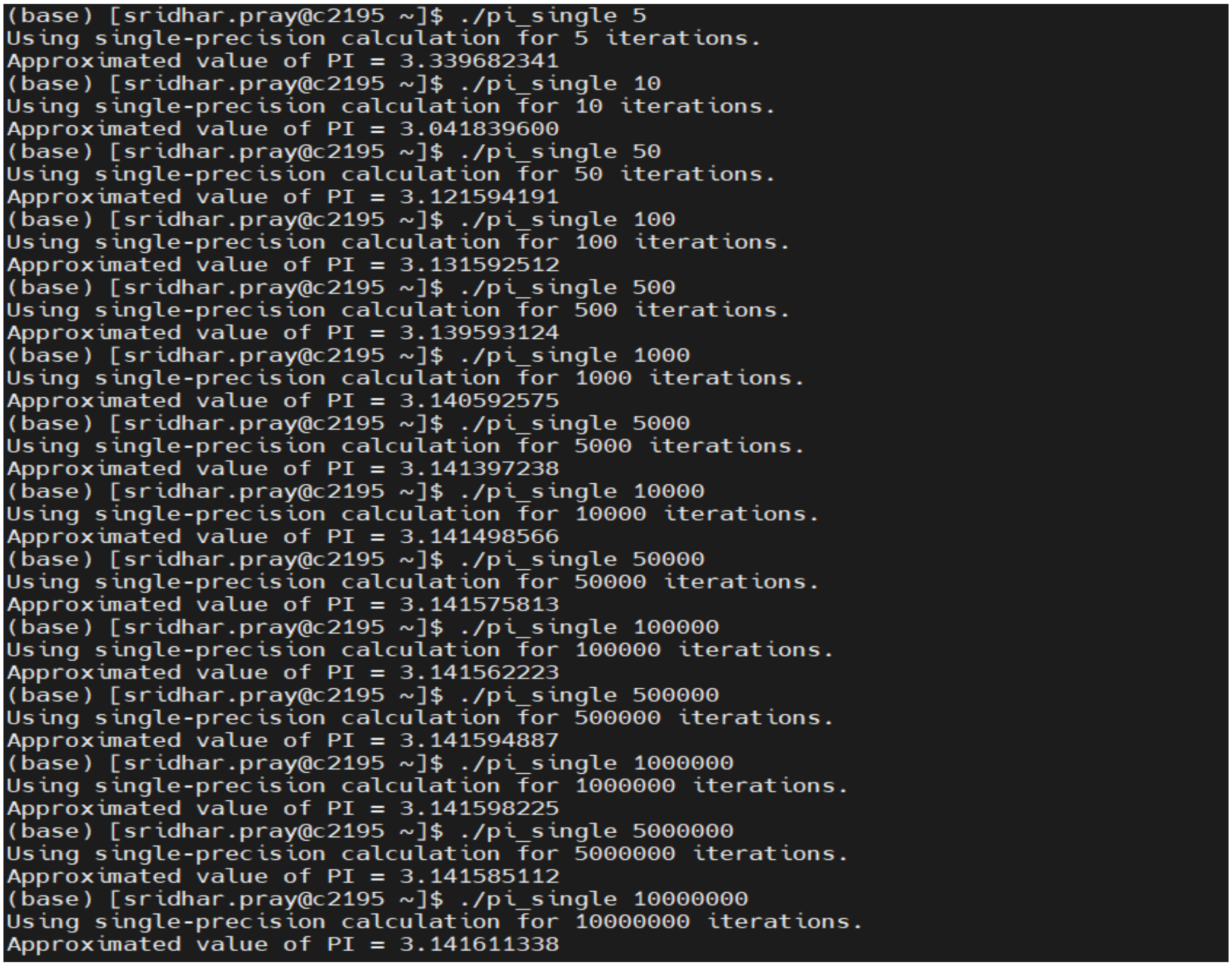
```
(base) [sridhar.pray@c2195 ~]$ ./pi_double 50000000
Using double-precision calculation for 50000000 iterations.
Approximated value of PI = 3.1415926335897715
(base) [sridhar.pray@c2195 ~]$ ./pi_double 100000000
Using double-precision calculation for 100000000 iterations.
Approximated value of PI = 3.1415926435898349
(base) [sridhar.pray@c2195 ~]$ ./pi_double 500000000
Using double-precision calculation for 500000000 iterations.
Approximated value of PI = 3.1415926515898298
(base) [sridhar.pray@c2195 ~]$ ./pi_double 1000000000
Using double-precision calculation for 1000000000 iterations.
Approximated value of PI = 3.1415926525897979
```

This is the output for single precision implementation:

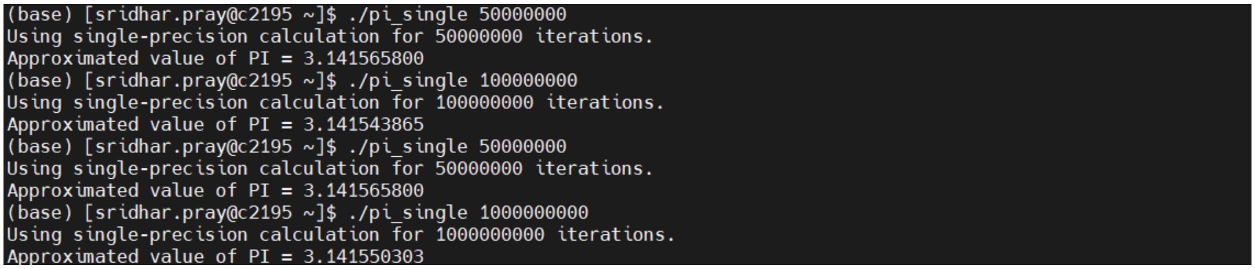


```
(base) [sridhar.pray@c2195 ~]$ nano pi_single.cu
(base) [sridhar.pray@c2195 ~]$ nvcc pi_single -o pi_single.cu
nvcc fatal   : Don't know what to do with 'pi_single'
(base) [sridhar.pray@c2195 ~]$ nvcc pi_single.cu -o pi_single
(base) [sridhar.pray@c2195 ~]$ ./pi_single 1
Using single-precision calculation for 1 iterations.
Approximated value of PI = 4.000000000
```

This is the output of 10 different iterations of single precision implementation:



```
(base) [sridhar.pray@c2195 ~]$ ./pi_single 5
Using single-precision calculation for 5 iterations.
Approximated value of PI = 3.339682341
(base) [sridhar.pray@c2195 ~]$ ./pi_single 10
Using single-precision calculation for 10 iterations.
Approximated value of PI = 3.041839600
(base) [sridhar.pray@c2195 ~]$ ./pi_single 50
Using single-precision calculation for 50 iterations.
Approximated value of PI = 3.121594191
(base) [sridhar.pray@c2195 ~]$ ./pi_single 100
Using single-precision calculation for 100 iterations.
Approximated value of PI = 3.131592512
(base) [sridhar.pray@c2195 ~]$ ./pi_single 500
Using single-precision calculation for 500 iterations.
Approximated value of PI = 3.139593124
(base) [sridhar.pray@c2195 ~]$ ./pi_single 1000
Using single-precision calculation for 1000 iterations.
Approximated value of PI = 3.140592575
(base) [sridhar.pray@c2195 ~]$ ./pi_single 5000
Using single-precision calculation for 5000 iterations.
Approximated value of PI = 3.141397238
(base) [sridhar.pray@c2195 ~]$ ./pi_single 10000
Using single-precision calculation for 10000 iterations.
Approximated value of PI = 3.141498566
(base) [sridhar.pray@c2195 ~]$ ./pi_single 50000
Using single-precision calculation for 50000 iterations.
Approximated value of PI = 3.141575813
(base) [sridhar.pray@c2195 ~]$ ./pi_single 100000
Using single-precision calculation for 100000 iterations.
Approximated value of PI = 3.141562223
(base) [sridhar.pray@c2195 ~]$ ./pi_single 500000
Using single-precision calculation for 500000 iterations.
Approximated value of PI = 3.141594887
(base) [sridhar.pray@c2195 ~]$ ./pi_single 1000000
Using single-precision calculation for 1000000 iterations.
Approximated value of PI = 3.141598225
(base) [sridhar.pray@c2195 ~]$ ./pi_single 5000000
Using single-precision calculation for 5000000 iterations.
Approximated value of PI = 3.141585112
(base) [sridhar.pray@c2195 ~]$ ./pi_single 10000000
Using single-precision calculation for 10000000 iterations.
Approximated value of PI = 3.141611338
```



```
(base) [sridhar.pray@c2195 ~]$ ./pi_single 50000000
Using single-precision calculation for 50000000 iterations.
Approximated value of PI = 3.141565800
(base) [sridhar.pray@c2195 ~]$ ./pi_single 100000000
Using single-precision calculation for 100000000 iterations.
Approximated value of PI = 3.141543865
(base) [sridhar.pray@c2195 ~]$ ./pi_single 50000000
Using single-precision calculation for 50000000 iterations.
Approximated value of PI = 3.141565800
(base) [sridhar.pray@c2195 ~]$ ./pi_single 1000000000
Using single-precision calculation for 1000000000 iterations.
Approximated value of PI = 3.141550303
```

Role precision plays in the rate of convergence:

The Leibniz series $\pi/4 = 1 - 1/3 + 1/5 - 1/7 + \cdots$ comes very slowly to π. Precision changes the rate of convergence because as more terms are added, their inputs get smaller. In single precision, these small inputs might blend into zero a lot faster than in double precision.

When you choose between single and double precision, the rate at which the Leibniz series approaches a correct number of π changes. It takes more computing power to use double precision, but the convergence is more reliable and stable, especially when there are more iterations. Single precision might make computations go faster, but the results will be less accurate and reach a point where more repetitions don't make a difference. In numerical analysis, this connection between accuracy and convergence is very important, especially in iterative methods and series estimates.