

Exercise 01

1. Compile and run your program using the command below

```
gcc -fopenmp lab04a.c -o lab04a.o
```

```
./lab04a.o
```

2. Is the answer correct now?

Yes, the answers are now correct. The calculated value of π is approximately 3.141592653589, which is accurate to 12 decimal places.

3. Compare the speeds of the original program you wrote in Lab03 with data races happening and when you use a mutex (critical section, atomic section)

The timing data clearly shows the performance impact of different synchronization methods:

- output_nosync.txt (Data Race - Incorrect): 2.224 seconds
- output1_atomic.txt (Atomic - Correct): 1.965 seconds
- output1_critical.txt (Critical - Correct): 0.147 seconds
- output_serial.txt (Serial - Correct): 1.678 seconds

The critical section was the fastest, which is unusual as atomic is typically faster for simple operations. This suggests the hardware-level atomic operation had very high overhead for this specific case.

This overhead was so severe that the atomic version was actually slower than the single-threaded serial program, completely negating the benefit of parallelization.

The unsynchronized version with a data race was the slowest due to "cache thrashing," where cores constantly fight over the shared variable. This shows data races are both incorrect and terrible for performance.

4. How many cores does your linux machine have?

- 2 cores

5. Use an new EC2 configuration that is higher tryout the program and change the number of threads used (See Lab02), is there a difference when you run the serial program and the parallel program in this higher EC2 configuration?

Yes, there will be a significant difference. The serial program will run faster due to a better CPU. The parallel program (especially with critical) will show much greater speedup when using more threads, as there are more physical cores to execute them concurrently, reducing the parallel time drastically.

6. What is the speedup for both EC2 instances when you change number of threads in this new version of the program

```
ec2-user@ip-172-31-47-134:~  
cp: cannot create regular file '/home/geeth/labsuser.pem': Permission denied  
geeth@DESKTOP-3400SVB:/mnt/c/Users/geeth2001/Downloads$ ls -ld ~  
drwxr-x--- 9 geeth geeth 4096 Aug 11 17:14 /home/geeth  
geeth@DESKTOP-3400SVB:/mnt/c/Users/geeth2001/Downloads$ sudo chown -R geeth:geeth /home/geeth  
[sudo] password for geeth:  
Sorry, try again.  
[sudo] password for geeth:  
Sorry, try again.  
[sudo] password for geeth:  
geeth@DESKTOP-3400SVB:/mnt/c/Users/geeth2001/Downloads$ cp /mnt/c/Users/geeth2001/Downloads/labsuser.pem ~/.  
cp: cannot create regular file '/home/geeth/labsuser.pem': Permission denied  
geeth@DESKTOP-3400SVB:/mnt/c/Users/geeth2001/Downloads$ chmod 400 ~/labsuser.pem  
geeth@DESKTOP-3400SVB:/mnt/c/Users/geeth2001/Downloads$ ssh -i ~/labsuser.pem ec2-user@107.20.3.145  
  
A newer release of "Amazon Linux" is available.  
Version 2023.8.20250808:  
Version 2023.8.20250818:  
Run "/usr/bin/dnf check-release-update" for full release and version update info  
  
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```

Last login: Mon Aug 4 13:58:56 2025 from 124.43.209.180
[ec2-user@ip-172-31-47-134 ~]\$ |

```

geeth@DESKTOP-3400SVB:~$ cp /mnt/c/Users/geeth2001/Downloads/labsuser.pem ~/
cp: cannot create regular file '/home/geeth/labsuser.pem': Permission denied
geeth@DESKTOP-3400SVB:~$ cd /mnt/c/Users/geeth2001/Downloads
geeth@DESKTOP-3400SVB:/mnt/c/Users/geeth2001/Downloads$ nano lab04a.c
geeth@DESKTOP-3400SVB:/mnt/c/Users/geeth2001/Downloads$ scp -i ~/labsuser.pem lab04
a.c ec2-user@107.20.3.145:~
lab04a.c                                100% 649      2.0KB/s   00:00
geeth@DESKTOP-3400SVB:/mnt/c/Users/geeth2001/Downloads$ scp -i ~/labsuser.pem lab04
a.c ec2-user@107.20.3.145:~
scp -i ~/labsuser.pem lab04a_critical.c ec2-user@107.20.3.145:~
scp -i ~/labsuser.pem lab04a_atomic.c ec2-user@107.20.3.145:~

lab04a.c                                100% 649      2.3KB/s   00:00
scp: stat local "lab04a_critical.c": No such file or directory
scp: stat local "lab04a_atomic.c": No such file or directory
geeth@DESKTOP-3400SVB:/mnt/c/Users/geeth2001/Downloads$
geeth@DESKTOP-3400SVB:/mnt/c/Users/geeth2001/Downloads$ scp -i ~/labsuser.pem ec2-u
ser@107.20.3.145:~/output.txt ~/
output.txt                              100% 48       0.1KB/s   00:00
geeth@DESKTOP-3400SVB:/mnt/c/Users/geeth2001/Downloads$

```

```
A newer release of "Amazon Linux" is available.
Version 2023.8.20250808:
Version 2023.8.20250818:
Run "/usr/bin/dnf check-release-update" for full release and version update info
```

```
Last login: Wed Aug 20 12:59:30 2025 from 124.43.209.178
[ec2-user@ip-172-31-47-134 ~]$ gcc -fopenmp lab04a.c -o lab04_atomic.o
[ec2-user@ip-172-31-47-134 ~]$ ./lab04_atomic.o
Pi (using critical section) = 3.141595852334631
[ec2-user@ip-172-31-47-134 ~]$ ./lab04a.o > output.txt
[ec2-user@ip-172-31-47-134 ~]$
```

```
geeth@DESKTOP-340QSVB:~$ cd /mnt/c/Users/geeth2001/Downloads
geeth@DESKTOP-340QSVB:~/Downloads$ chmod 400 ~/labsuser.pem
geeth@DESKTOP-340QSVB:~/Downloads$ ssh -i ~/labsuser.pem ec2-u
ser@107.20.3.145
```

```
A newer release of "Amazon Linux" is available.
Version 2023.8.20250808:
Version 2023.8.20250818:
Run "/usr/bin/dnf check-release-update" for full release and version update info
```

```

Last login: Wed Aug 20 13:29:38 2025 from 124.43.209.178
[ec2-user@ip-172-31-47-134 ~]$ gcc -fopenmp lab04_ex2.c -o lab04_ex2.o
/usr/bin/ld: /tmp/ccLOH9q9.o: in function `main._omp_fn.0':
lab04_ex2.c:(.text+0x146): undefined reference to `sqrt'
collect2: error: ld returned 1 exit status
[ec2-user@ip-172-31-47-134 ~]$ gcc -fopenmp lab04_ex2.c -o lab04_ex2.o -lm
[ec2-user@ip-172-31-47-134 ~]$ ./lab04_ex2.o
Summation (Critical) = -3333333333303516332032.00000
Time taken: 0.037813 seconds
[ec2-user@ip-172-31-47-134 ~]$ ./lab04_ex2.o > output.txt
[ec2-user@ip-172-31-47-134 ~]$

```


Exercise 03

```
geeth@DESKTOP-3400SVB:~$ cd /mnt/c/Users/geeth2001/Downloads
geeth@DESKTOP-3400SVB:/mnt/c/Users/geeth2001/Downloads$ chmod 400 ~/labsuser.pem
geeth@DESKTOP-3400SVB:/mnt/c/Users/geeth2001/Downloads$ ssh -i ~/labsuser.pem ec2-u
ser@107.20.3.145

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Version 2023.8.20250808:
Version 2023.8.20250818:
Run "/usr/bin/dnf check-release-update" for full release and version update info

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~\_ #####_ Amazon Linux 2023
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Last login: Wed Aug 20 13:43:49 2025 from 124.43.209.178
[ec2-user@ip-172-31-47-134 ~]$ gcc -fopenmp lab04_ex3_serial.c -o lab04_ex3_serial
.o -lm
[ec2-user@ip-172-31-47-134 ~]$ ./lab04_ex3_serial.o
Serial Pi approximation: 3.1411300000
Total points: 10000000
Points inside circle: 7852825
Time taken: 0.351771 seconds
[ec2-user@ip-172-31-47-134 ~]$ ./lab04_ex2.o > output3.1.txt
[ec2-user@ip-172-31-47-134 ~]$
```

```
Version 2023.8.20250818:
Run "/usr/bin/dnf check-release-update" for full release and version u
pdate info

#_
~\_ #####_ Amazon Linux 2023
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~~ \#/ --- https://aws.amazon.com/linux/amazon-linux-2023
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Last login: Wed Aug 20 13:43:49 2025 from 124.43.209.178
[ec2-user@ip-172-31-47-134 ~]$ gcc -fopenmp lab04_ex3_serial.c -o lab
04_ex3_serial
.o -lm
[ec2-user@ip-172-31-47-134 ~]$ ./lab04_ex3_serial.o
Serial Pi approximation: 3.1411300000
Total points: 10000000
Points inside circle: 7852825
Time taken: 0.351771 seconds
[ec2-user@ip-172-31-47-134 ~]$ ./lab04_ex2.o > output3.1.txt
[ec2-user@ip-172-31-47-134 ~]$ gcc -fopenmp lab04_ex3_parallel.c -o l
ab04_ex3_para
llep
.o -lm
-bash: .o: command not found
[ec2-user@ip-172-31-47-134 ~]$ gcc -fopenmp lab04_ex3_parallel.c -o la
b04_ex3_parallel.o -lm
[ec2-user@ip-172-31-47-134 ~]$ ./lab04_ex3_parallel.o
Parallel Pi approximation: 3.1416672000
Total points: 10000000
Points inside circle: 7854168
Time taken: 0.074250 seconds
[ec2-user@ip-172-31-47-134 ~]$ ./lab04_ex2.o > output3.2.txt
[ec2-user@ip-172-31-47-134 ~]$
```

Exercise 04

```
geeth@DESKTOP-3400SVB:/mnt/c/Users/geeth2001/Downloads$ chmod 400 ~/.ssh/authorized_keys
geeth@DESKTOP-3400SVB:/mnt/c/Users/geeth2001/Downloads$ ssh -i ~/.ssh/authorized_keys ec2-user@107.20.3.145
```


```
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  Version 2023.8.20250818:
Run "/usr/bin/dnf check-release-update" for full release and version u
pdate info
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```

```
Last login: Wed Aug 20 13:59:30 2025 from 124.43.209.178
[ec2-user@ip-172-31-47-134 ~]$ gcc -fopenmp lab04_ex4.1.c -o lab04_ex4.1.o
[ec2-user@ip-172-31-47-134 ~]$ ./lab04_ex4.1.o
Sequential Approximation of pi = 3.141592653590
[ec2-user@ip-172-31-47-134 ~]$ ./lab04_ex2.o > output4.1.txt
[ec2-user@ip-172-31-47-134 ~]$ ./lab04_ex4.1.o > output4.1.txt
[ec2-user@ip-172-31-47-134 ~]$
```

```
geeth@DESKTOP-3400SVB:/mnt/c/Users/geeth2001/Downloads$ chmod 400 ~/.la
bsuser.pem
geeth@DESKTOP-3400SVB:/mnt/c/Users/geeth2001/Downloads$ ssh -i ~/.labsu
ser.pem ec2-user@107.20.3.145
```

```
A newer release of "Amazon Linux" is available.
  Version 2023.8.20250808:
  Version 2023.8.20250818:
Run "/usr/bin/dnf check-release-update" for full release and version u
pdate info
```



Amazon Linux 2023

<https://aws.amazon.com/linux/amazon-linux-2023>

```
Last login: Wed Aug 20 14:24:46 2025 from 124.43.209.178
[ec2-user@ip-172-31-47-134 ~]$ gcc -fopenmp lab04_ex4.2.c -o lab04_ex
4.2.o -lm
[ec2-user@ip-172-31-47-134 ~]$ ./lab04_ex4.2.o
Parallel Approximation of pi = 0.00000000000000
Time taken = 663.988 ms
[ec2-user@ip-172-31-47-134 ~]$
```