High Performance Computing

Assignment 3

Theory Questions

1. Profiling is program analysis to check how an application is doing, its performance and identify areas that need optimizations. The classification into the different types of profilers is done based on how they collect their information during the execution of a program.

   Event Profiling
   Java, .NET, Python, Ruby are Even-based profilers. These programming languages use an interface or profiling agent like a Profiling API during runtime for trapping events like calls, class-load, unload, thread enter and leave
   Event Profiling captures a subset of event from an application during the execution of the program and collects data like memory usage.
   Advantage :
   - It can be performed with minimal overhead on the application making it suitable for high performance applications.
   - It ca identify bottlenecks during program, how much space a program is taking, where it is going wrong
   - It can be suitable for HPC applications since it can be used with low overhead

   Disadvantage:
   - Since it considers a subset of the program, it does not capture all events in the application therefore it can miss some important parts of the program during execution
   - Therefore when using it for HPC, basically a heterogenous network, it can be disadvantageous as it only takes a subset of event, but in HPC multiple critical events are running in parallel which might make lead to missing on some important data

   Instrumentation Profiling
   In Instrumentation Profiling, we add instruction to the program itself to collect required information during execution.
   Advantage:
   - Instrumentation allows us to determine the level of control and the amount of time resolution that is available to the profilers
   - We can get detailed information and all information we like in a comprehensive manner

   Disadvantage:
   - This can affect the program performance
   - In high performance application, it can case a lot of unnecessary and additional overhead that is unsuitable in a already ‘busy’ environment
   - Instrumentation profiling can be time consuming

- Instrumentation profiling can be difficult to implement in a complex HPC environment

Statistical Profiling
When sampling profiling is done, the results are not exact but a statistical approximation. The actual value is usually n times the sampling period.

Advantage:

- Statistical Profiling allows in identifying the performance data which are statistically accurate
- Helpful in identifying trends and patterns in the data

Disadvantage:

- Time consuming as it takes time to analyse the data after collection of data
- In heterogenous environments, it can be difficult since there are multiple applications, machines, too much going on to be able to collect all data accurately and analyze it before producing the result
- This means, there will also be unnecessary overhead

2. Some obvious parameters to consider and investigate when evaluating the performance of a file system and storage configuration is:
    - Latency: trying to get the data form the storage
        - Read/Write/IO operations: Time it takes when trying to open, read or create and write in a file of a very large size. How many operations can be performed pr second
    - Throughput: Perform benchmarking to evaluate the amount of data that can be read or written from/into a file typically for a huge size of data
    - For a large network with multiple nodes, checking if nodes are able to communicate with each other at any given time over a network with consistency and least possible latency/interruptions/loss of data
    - Check the bottleneck links for the file system to see how quickly it gets saturated and increase the latency
    - What level of storage the file systems are stored in? What I mean by this is let's say data that is constantly fetched is stored in cache to that it is immediately available when it is requested

ZFS - robust data integrity features and support for advanced storage features such as snapshots and replication. Works well on large disks and joining multiple disks

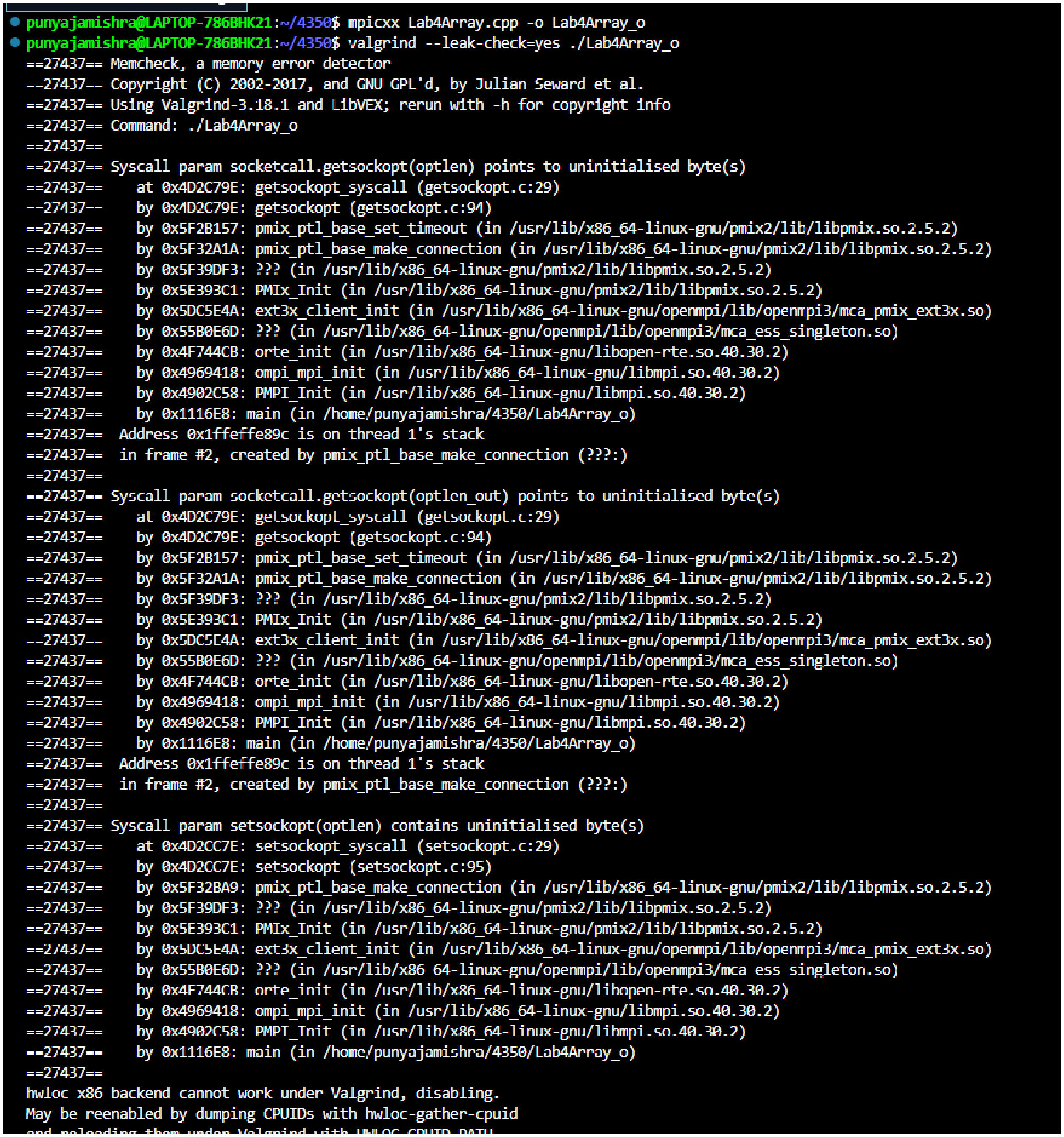
BTRFS is known for its support for transparent compression and snapshotting. Built to deal with fault tolerance, management and data protection in storage systems

ReFS is designed specifically for use with Microsoft's Windows operating system, and it includes features such as built-in support for advanced storage technologies such as Storage Spaces Direct over multiple remote users on a network connection

Programming Questions

1. **Use VampirTrace (or score-p if it doesn't want to behave for you) or Google profiler to profile one of your applications either in this course or from another (note that since these are fairly simple programs it won't show you much, but it's something to say you are familiar with profiling). The point of this is just that you've seen how to profile an application, not that the results are particularly meaningful**

Running Lab4Array.cpp with valgrind



```
● punyajamishra@LAPTOP-786BHK21:~/4350$ mpicxx Lab4Array.cpp -o Lab4Array_o
● punyajamishra@LAPTOP-786BHK21:~/4350$ valgrind --leak-check=yes ./Lab4Array_o
  ==27437== Memcheck, a memory error detector
  ==27437== Copyright (C) 2002-2017, and GNU GPL'd, by Julian Seward et al.
  ==27437== Using Valgrind-3.18.1 and LibVEX; rerun with -h for copyright info
  ==27437== Command: ./Lab4Array_o
  ==27437==
  ==27437== Syscall param socketcall.getsockopt(optlen) points to uninitialised byte(s)
  ==27437==    at 0x4D2C79E: getsockopt_syscall (getsockopt.c:29)
  ==27437==    by 0x4D2C79E: getsockopt (getsockopt.c:94)
  ==27437==    by 0x5F2B157: pmix_ptl_base_set_timeout (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
  ==27437==    by 0x5F32A1A: pmix_ptl_base_make_connection (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
  ==27437==    by 0x5F39DF3: ??? (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
  ==27437==    by 0x5E393C1: PMIx_Init (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
  ==27437==    by 0x5DC5E4A: ext3x_client_init (in /usr/lib/x86_64-linux-gnu/openmpi/lib/openmpi3/mca_pmix_ext3x.so)
  ==27437==    by 0x55B0E6D: ??? (in /usr/lib/x86_64-linux-gnu/openmpi/lib/openmpi3/mca_ess_singleton.so)
  ==27437==    by 0x4F744CB: orte_init (in /usr/lib/x86_64-linux-gnu/libopen-rte.so.40.30.2)
  ==27437==    by 0x4969418: ompi_mpi_init (in /usr/lib/x86_64-linux-gnu/libmpi.so.40.30.2)
  ==27437==    by 0x4902C58: PMPI_Init (in /usr/lib/x86_64-linux-gnu/libmpi.so.40.30.2)
  ==27437==    by 0x1116E8: main (in /home/punyajamishra/4350/Lab4Array_o)
  ==27437==  Address 0x1ffeffe89c is on thread 1's stack
  ==27437==  in frame #2, created by pmix_ptl_base_make_connection (???:)
  ==27437==
  ==27437== Syscall param socketcall.getsockopt(optlen_out) points to uninitialised byte(s)
  ==27437==    at 0x4D2C79E: getsockopt_syscall (getsockopt.c:29)
  ==27437==    by 0x4D2C79E: getsockopt (getsockopt.c:94)
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  ==27437==    by 0x5F32A1A: pmix_ptl_base_make_connection (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
  ==27437==    by 0x5F39DF3: ??? (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
  ==27437==    by 0x5E393C1: PMIx_Init (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
  ==27437==    by 0x5DC5E4A: ext3x_client_init (in /usr/lib/x86_64-linux-gnu/openmpi/lib/openmpi3/mca_pmix_ext3x.so)
  ==27437==    by 0x55B0E6D: ??? (in /usr/lib/x86_64-linux-gnu/openmpi/lib/openmpi3/mca_ess_singleton.so)
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  ==27437==  in frame #2, created by pmix_ptl_base_make_connection (???:)
  ==27437==
  ==27437== Syscall param setsockopt(optlen) contains uninitialised byte(s)
  ==27437==    at 0x4D2CC7E: setsockopt_syscall (setsockopt.c:29)
  ==27437==    by 0x4D2CC7E: setsockopt (setsockopt.c:95)
  ==27437==    by 0x5F32BA9: pmix_ptl_base_make_connection (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
  ==27437==    by 0x5F39DF3: ??? (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
  ==27437==    by 0x5E393C1: PMIx_Init (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
  ==27437==    by 0x5DC5E4A: ext3x_client_init (in /usr/lib/x86_64-linux-gnu/openmpi/lib/openmpi3/mca_pmix_ext3x.so)
  ==27437==    by 0x55B0E6D: ??? (in /usr/lib/x86_64-linux-gnu/openmpi/lib/openmpi3/mca_ess_singleton.so)
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  ==27437==    by 0x4969418: ompi_mpi_init (in /usr/lib/x86_64-linux-gnu/libmpi.so.40.30.2)
  ==27437==    by 0x4902C58: PMPI_Init (in /usr/lib/x86_64-linux-gnu/libmpi.so.40.30.2)
  ==27437==    by 0x1116E8: main (in /home/punyajamishra/4350/Lab4Array_o)
  ==27437==
  hwloc x86 backend cannot work under Valgrind, disabling.
  May be reenabled by dumping CPUIDs with hwloc-gather-cpuid
  and reloading them under Valgrind with HWLOC_CPUID_PATH
```
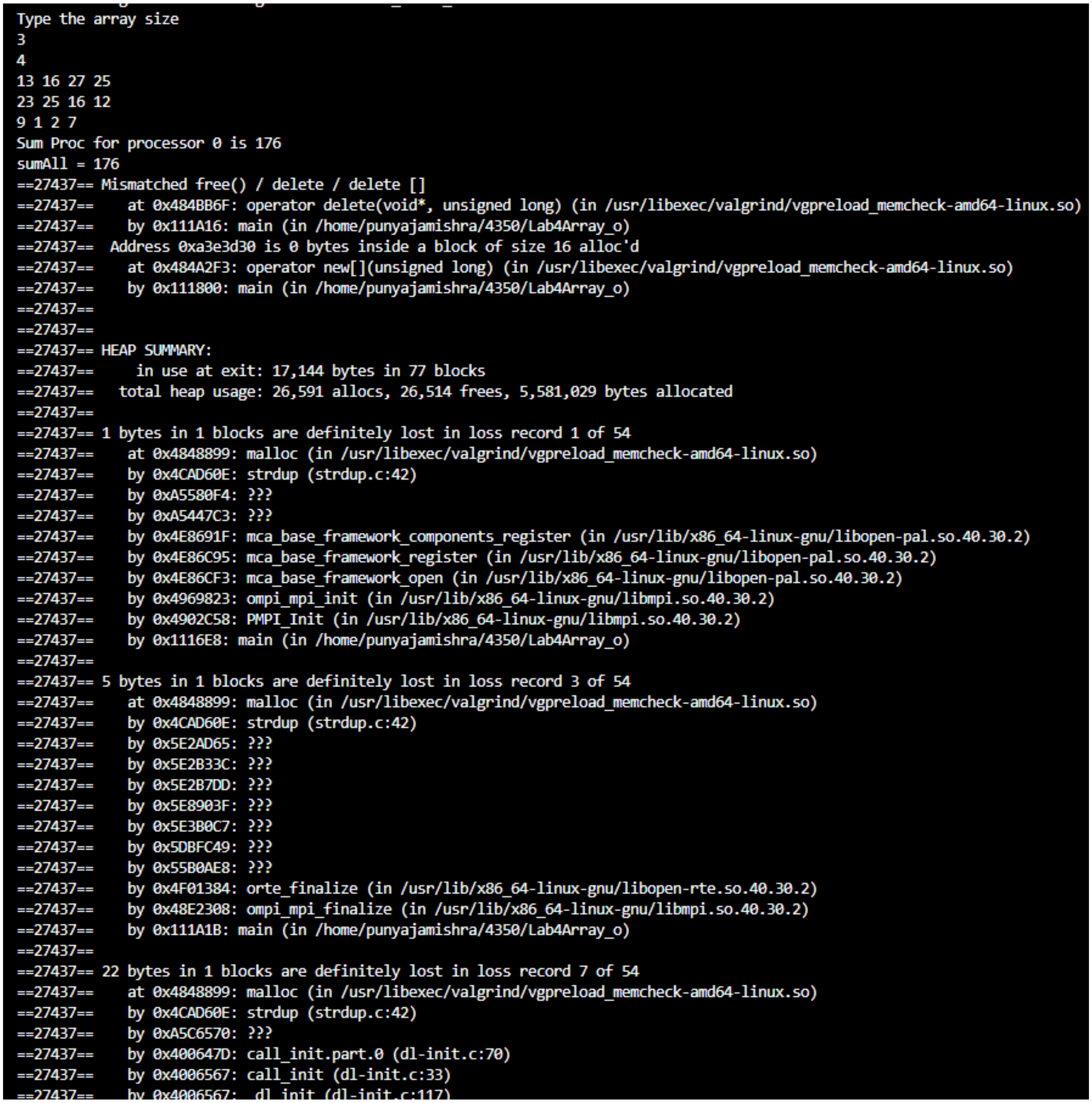
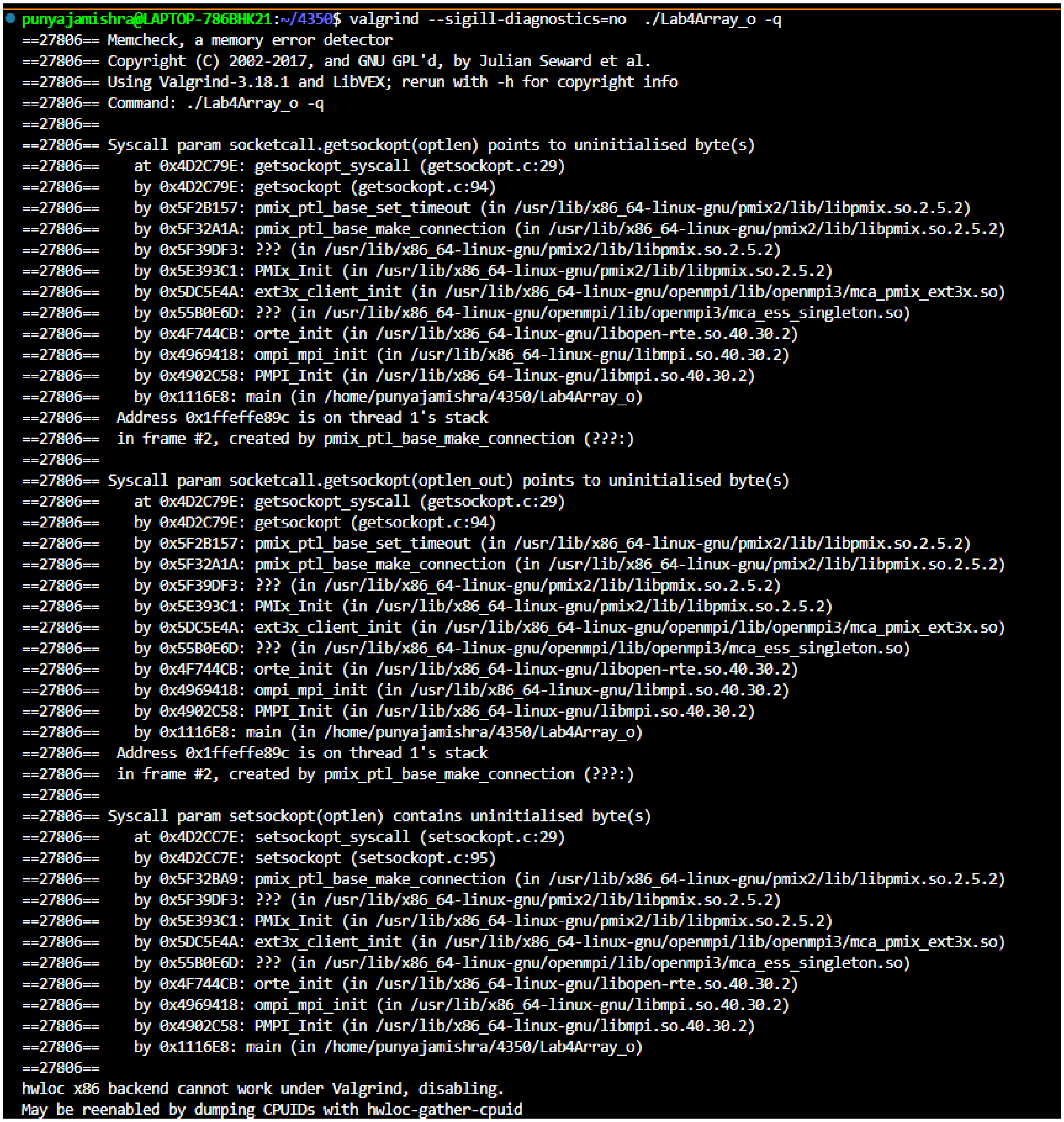



```
Type the array size
3
4
13 16 27 25
23 25 16 12
9 1 2 7
Sum Proc for processor 0 is 176
sumAll = 176
==27437== Mismatched free() / delete / delete []
==27437==    at 0x484BB6F: operator delete(void*, unsigned long) (in /usr/libexec/valgrind/vgpreload_memcheck-amd64-linux.so)
==27437==    by 0x111A16: main (in /home/punyajamishra/4350/Lab4Array_o)
==27437==  Address 0xa3e3d30 is 0 bytes inside a block of size 16 alloc'd
==27437==    at 0x484A2F3: operator new[](unsigned long) (in /usr/libexec/valgrind/vgpreload_memcheck-amd64-linux.so)
==27437==    by 0x111800: main (in /home/punyajamishra/4350/Lab4Array_o)
==27437==
==27437==
==27437== HEAP SUMMARY:
==27437==     in use at exit: 17,144 bytes in 77 blocks
==27437==   total heap usage: 26,591 allocs, 26,514 frees, 5,581,029 bytes allocated
==27437==
==27437== 1 bytes in 1 blocks are definitely lost in loss record 1 of 54
==27437==    at 0x4848899: malloc (in /usr/libexec/valgrind/vgpreload_memcheck-amd64-linux.so)
==27437==    by 0x4CAD60E: strdup (strdup.c:42)
==27437==    by 0xA5580F4: ???
==27437==    by 0xA5447C3: ???
==27437==    by 0x4E8691F: mca_base_framework_components_register (in /usr/lib/x86_64-linux-gnu/libopen-pal.so.40.30.2)
==27437==    by 0x4E86C95: mca_base_framework_register (in /usr/lib/x86_64-linux-gnu/libopen-pal.so.40.30.2)
==27437==    by 0x4E86CF3: mca_base_framework_open (in /usr/lib/x86_64-linux-gnu/libopen-pal.so.40.30.2)
==27437==    by 0x4969823: ompi_mpi_init (in /usr/lib/x86_64-linux-gnu/libmpi.so.40.30.2)
==27437==    by 0x4902C58: PMPI_Init (in /usr/lib/x86_64-linux-gnu/libmpi.so.40.30.2)
==27437==    by 0x1116E8: main (in /home/punyajamishra/4350/Lab4Array_o)
==27437==
==27437== 5 bytes in 1 blocks are definitely lost in loss record 3 of 54
==27437==    at 0x4848899: malloc (in /usr/libexec/valgrind/vgpreload_memcheck-amd64-linux.so)
==27437==    by 0x4CAD60E: strdup (strdup.c:42)
==27437==    by 0x5E2AD65: ???
==27437==    by 0x5E2B33C: ???
==27437==    by 0x5E2B7DD: ???
==27437==    by 0x5E8903F: ???
==27437==    by 0x5E3B0C7: ???
==27437==    by 0x5DBFC49: ???
==27437==    by 0x55B0AE8: ???
==27437==    by 0x4F01384: orte_finalize (in /usr/lib/x86_64-linux-gnu/libopen-rte.so.40.30.2)
==27437==    by 0x48E2308: ompi_mpi_finalize (in /usr/lib/x86_64-linux-gnu/libmpi.so.40.30.2)
==27437==    by 0x111A1B: main (in /home/punyajamishra/4350/Lab4Array_o)
==27437==
==27437== 22 bytes in 1 blocks are definitely lost in loss record 7 of 54
==27437==    at 0x4848899: malloc (in /usr/libexec/valgrind/vgpreload_memcheck-amd64-linux.so)
==27437==    by 0x4CAD60E: strdup (strdup.c:42)
==27437==    by 0xA5C6570: ???
==27437==    by 0x400647D: call_init.part.0 (dl-init.c:70)
==27437==    by 0x4006567: call_init (dl-init.c:33)
==27437==    by 0x4006567: _dl_init (dl-init.c:117)
```

--sigill-diagnostics=<yes|no> [default: yes]

Enable/disable printing of illegal instruction diagnostics. Enabled by default, but defaults to disabled when --quiet is given. The default can always be explicitly overridden by giving this option.

When enabled, a warning message will be printed, along with some diagnostics, whenever an instruction is encountered that Valgrind cannot decode or translate, before the program is given a SIGILL signal. Often an illegal instruction indicates a bug in the program or missing support for the particular instruction in Valgrind. But some programs do deliberately try to execute an instruction that might be missing and trap the SIGILL signal to detect processor features. Using this flag makes it possible to avoid the diagnostic output that you would otherwise get in such cases



```
punyajamishra@LAPTOP-786BHK21:~/4350$ valgrind --sigill-diagnostics=no  ./Lab4Array_o -q
==27806== Memcheck, a memory error detector
==27806== Copyright (C) 2002-2017, and GNU GPL'd, by Julian Seward et al.
==27806== Using Valgrind-3.18.1 and LibVEX; rerun with -h for copyright info
==27806== Command: ./Lab4Array_o -q
==27806==
==27806== Syscall param socketcall.getsockopt(optlen) points to uninitialised byte(s)
==27806==    at 0x4D2C79E: getsockopt_syscall (getsockopt.c:29)
==27806==    by 0x4D2C79E: getsockopt (getsockopt.c:94)
==27806==    by 0x5F2B157: pmix_ptl_base_set_timeout (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
==27806==    by 0x5F32A1A: pmix_ptl_base_make_connection (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
==27806==    by 0x5F39DF3: ??? (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
==27806==    by 0x5E393C1: PMIx_Init (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
==27806==    by 0x5DC5E4A: ext3x_client_init (in /usr/lib/x86_64-linux-gnu/openmpi/lib/openmpi3/mca_pmix_ext3x.so)
==27806==    by 0x55B0E6D: ??? (in /usr/lib/x86_64-linux-gnu/openmpi/lib/openmpi3/mca_ess_singleton.so)
==27806==    by 0x4F744CB: orte_init (in /usr/lib/x86_64-linux-gnu/libopen-rte.so.40.30.2)
==27806==    by 0x4969418: ompi_mpi_init (in /usr/lib/x86_64-linux-gnu/libmpi.so.40.30.2)
==27806==    by 0x4902C58: PMPI_Init (in /usr/lib/x86_64-linux-gnu/libmpi.so.40.30.2)
==27806==    by 0x1116E8: main (in /home/punyajamishra/4350/Lab4Array_o)
==27806==  Address 0x1ffeffe89c is on thread 1's stack
==27806==  in frame #2, created by pmix_ptl_base_make_connection (???:)
==27806==
==27806== Syscall param socketcall.getsockopt(optlen_out) points to uninitialised byte(s)
==27806==    at 0x4D2C79E: getsockopt_syscall (getsockopt.c:29)
==27806==    by 0x4D2C79E: getsockopt (getsockopt.c:94)
==27806==    by 0x5F2B157: pmix_ptl_base_set_timeout (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
==27806==    by 0x5F32A1A: pmix_ptl_base_make_connection (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
==27806==    by 0x5F39DF3: ??? (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
==27806==    by 0x5E393C1: PMIx_Init (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
==27806==    by 0x5DC5E4A: ext3x_client_init (in /usr/lib/x86_64-linux-gnu/openmpi/lib/openmpi3/mca_pmix_ext3x.so)
==27806==    by 0x55B0E6D: ??? (in /usr/lib/x86_64-linux-gnu/openmpi/lib/openmpi3/mca_ess_singleton.so)
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==27806==
==27806== Syscall param setsockopt(optlen) contains uninitialised byte(s)
==27806==    at 0x4D2CC7E: setsockopt_syscall (setsockopt.c:29)
==27806==    by 0x4D2CC7E: setsockopt (setsockopt.c:95)
==27806==    by 0x5F32BA9: pmix_ptl_base_make_connection (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
==27806==    by 0x5F39DF3: ??? (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
==27806==    by 0x5E393C1: PMIx_Init (in /usr/lib/x86_64-linux-gnu/pmix2/lib/libpmix.so.2.5.2)
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==27806==    by 0x55B0E6D: ??? (in /usr/lib/x86_64-linux-gnu/openmpi/lib/openmpi3/mca_ess_singleton.so)
==27806==    by 0x4F744CB: orte_init (in /usr/lib/x86_64-linux-gnu/libopen-rte.so.40.30.2)
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==27806==    by 0x1116E8: main (in /home/punyajamishra/4350/Lab4Array_o)
==27806==
hwloc x86 backend cannot work under Valgrind, disabling.
May be reenabled by dumping CPUIDs with hwloc-gather-cpuid
```
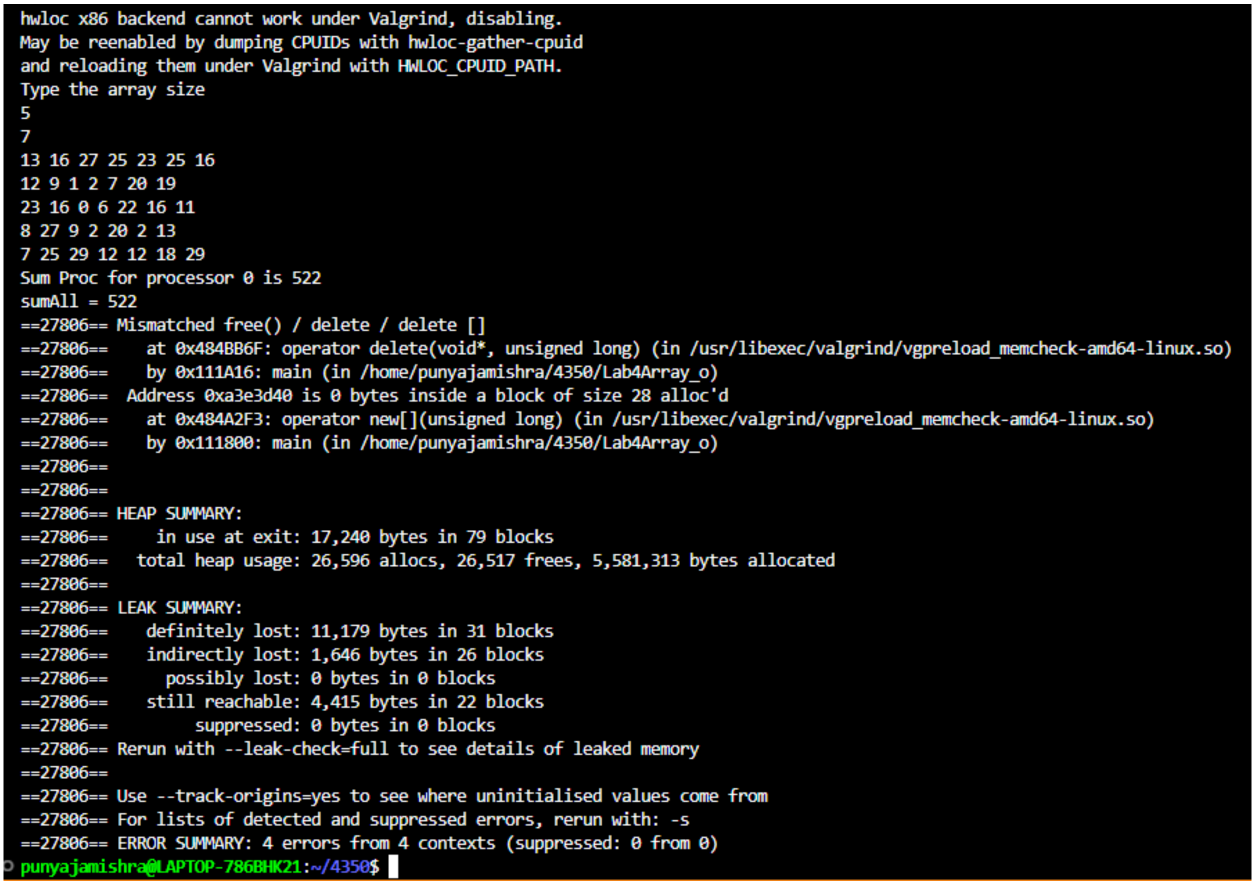
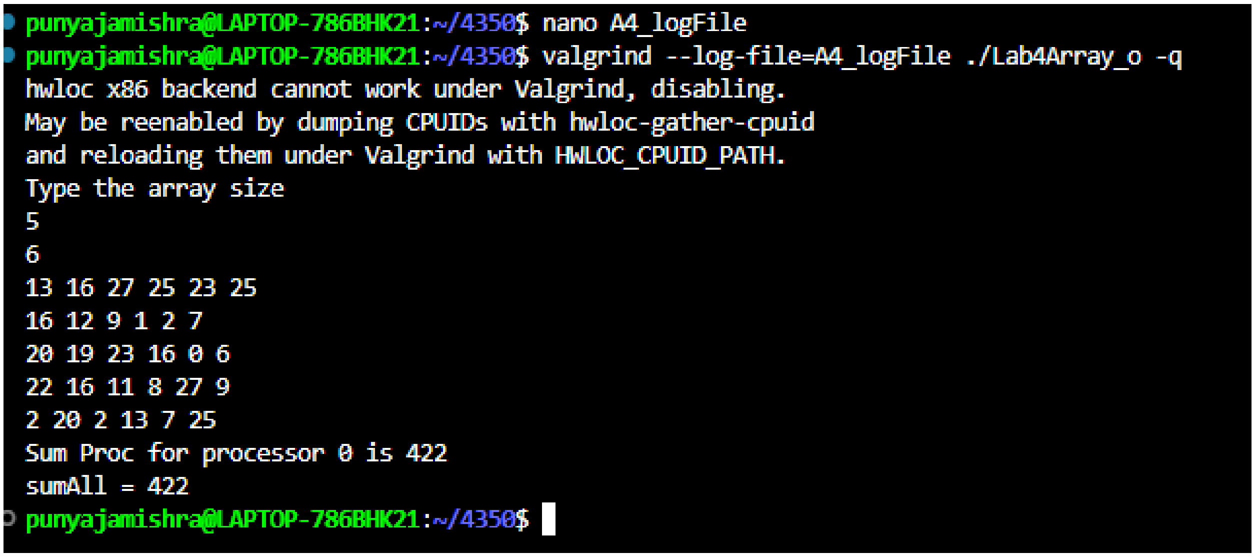



```
hwloc x86 backend cannot work under Valgrind, disabling.
May be reenabled by dumping CPUIDs with hwloc-gather-cpuid
and reloading them under Valgrind with HWLOC_CPUID_PATH.
Type the array size
5
7
13 16 27 25 23 25 16
12 9 1 2 7 20 19
23 16 0 6 22 16 11
8 27 9 2 20 2 13
7 25 29 12 12 18 29
Sum Proc for processor 0 is 522
sumAll = 522
==27806== Mismatched free() / delete / delete []
==27806==    at 0x484BB6F: operator delete(void*, unsigned long) (in /usr/libexec/valgrind/vgpreload_memcheck-amd64-linux.so)
==27806==    by 0x111A16: main (in /home/punyajamishra/4350/Lab4Array_o)
==27806==  Address 0xa3e3d40 is 0 bytes inside a block of size 28 alloc'd
==27806==    at 0x484A2F3: operator new[](unsigned long) (in /usr/libexec/valgrind/vgpreload_memcheck-amd64-linux.so)
==27806==    by 0x111800: main (in /home/punyajamishra/4350/Lab4Array_o)
==27806==
==27806==
==27806== HEAP SUMMARY:
==27806==     in use at exit: 17,240 bytes in 79 blocks
==27806==   total heap usage: 26,596 allocs, 26,517 frees, 5,581,313 bytes allocated
==27806==
==27806== LEAK SUMMARY:
==27806==    definitely lost: 11,179 bytes in 31 blocks
==27806==    indirectly lost: 1,646 bytes in 26 blocks
==27806==      possibly lost: 0 bytes in 0 blocks
==27806==    still reachable: 4,415 bytes in 22 blocks
==27806==         suppressed: 0 bytes in 0 blocks
==27806== Rerun with --leak-check=full to see details of leaked memory
==27806==
==27806== Use --track-origins=yes to see where uninitialised values come from
==27806== For lists of detected and suppressed errors, rerun with: -s
==27806== ERROR SUMMARY: 4 errors from 4 contexts (suppressed: 0 from 0)
punyajamishra@LAPTOP-786BHK21:~/4350$ 
```

--log-file=<filename>

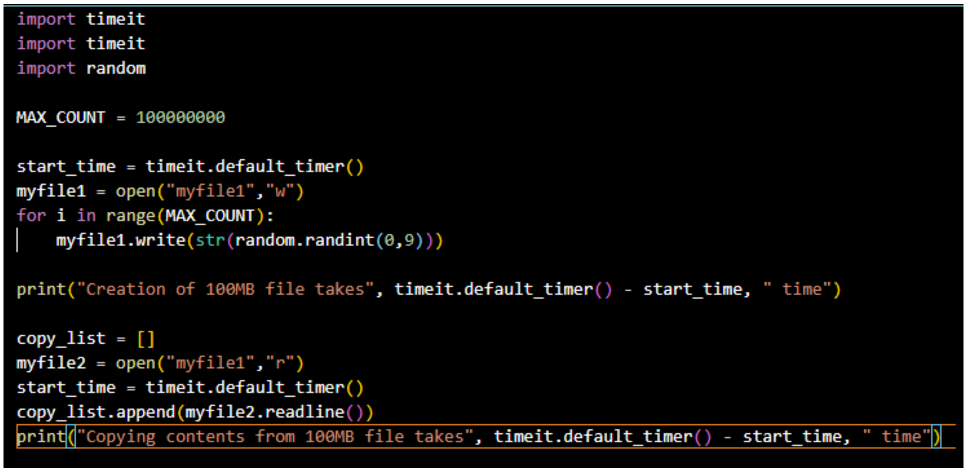
Specifies that Valgrind should send all of its messages to the specified file. If the file name is empty, it causes an abort. There are three special format specifiers that can be used in the file name.



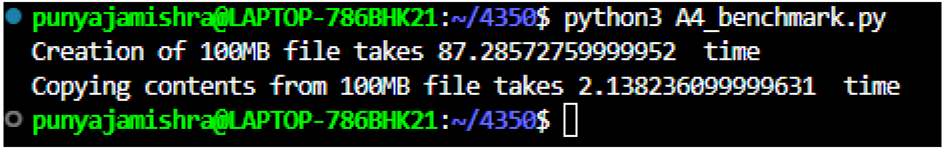
```
punyajamishra@LAPTOP-786BHK21:~/4350$ nano A4_logFile
punyajamishra@LAPTOP-786BHK21:~/4350$ valgrind --log-file=A4_logFile ./Lab4Array_o -q
hwloc x86 backend cannot work under Valgrind, disabling.
May be reenabled by dumping CPUIDs with hwloc-gather-cpuid
and reloading them under Valgrind with HWLOC_CPUID_PATH.
Type the array size
5
6
13 16 27 25 23 25
16 12 9 1 2 7
20 19 23 16 0 6
22 16 11 8 27 9
2 20 2 13 7 25
Sum Proc for processor 0 is 422
sumAll = 422
punyajamishra@LAPTOP-786BHK21:~/4350$ 
```

2. **Write a simple benchmark application to test the performance of a relatively large (>100MB) file copy, and a simple test of repeatedly reading and writing from several dozen small files (< 1MB each). This is related of course to theory question 2, and feel free to improve on the experiment or visualise the results. (You can do this in python easily enough). Note: You can do this in windows or Linux or Native Mac OSX**
   Language: Python | Doing benchmarking using default using ‘timeit’

   For big 100MB file

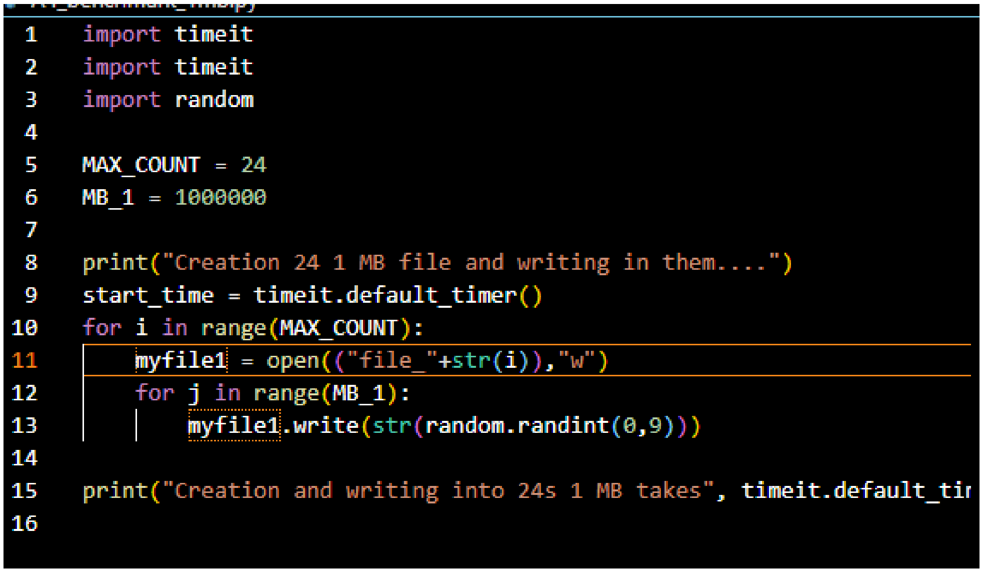


```
import timeit
import timeit
import random

MAX_COUNT = 100000000

start_time = timeit.default_timer()
myfile1 = open("myfile1","w")
for i in range(MAX_COUNT):
    myfile1.write(str(random.randint(0,9)))

print("Creation of 100MB file takes", timeit.default_timer() - start_time, " time")

copy_list = []
myfile2 = open("myfile1","r")
start_time = timeit.default_timer()
copy_list.append(myfile2.readline())
print("Copying contents from 100MB file takes", timeit.default_timer() - start_time, " time")
```

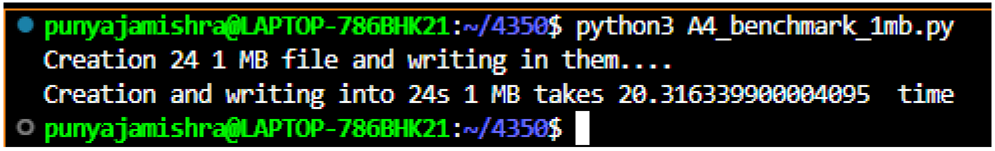


```
punyajamishra@LAPTOP-786BHK21:~/4350$ python3 A4_benchmark.py
Creation of 100MB file takes 87.28572759999952  time
Copying contents from 100MB file takes 2.138236099999631  time
punyajamishra@LAPTOP-786BHK21:~/4350$ 
```

For multiple small files (1mb) each

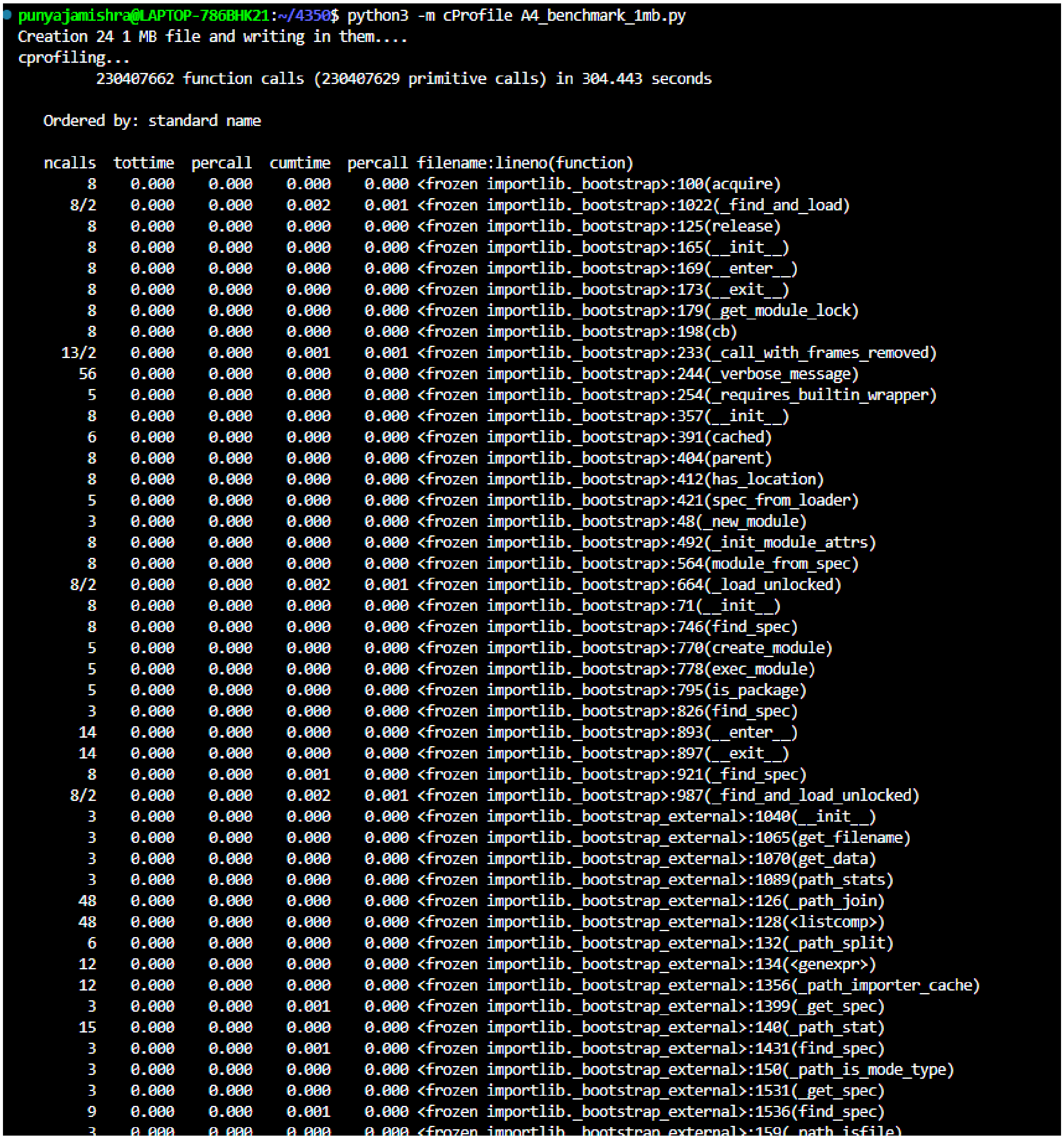


```
import timeit
import timeit
import random

MAX_COUNT = 24
MB_1 = 1000000

print("Creation 24 1 MB file and writing in them....")
start_time = timeit.default_timer()
for i in range(MAX_COUNT):
    myfile1 = open(("file_"+str(i)),"w")
    for j in range(MB_1):
        myfile1.write(str(random.randint(0,9)))

print("Creation and writing into 24s 1 MB takes", timeit.default_ti

```

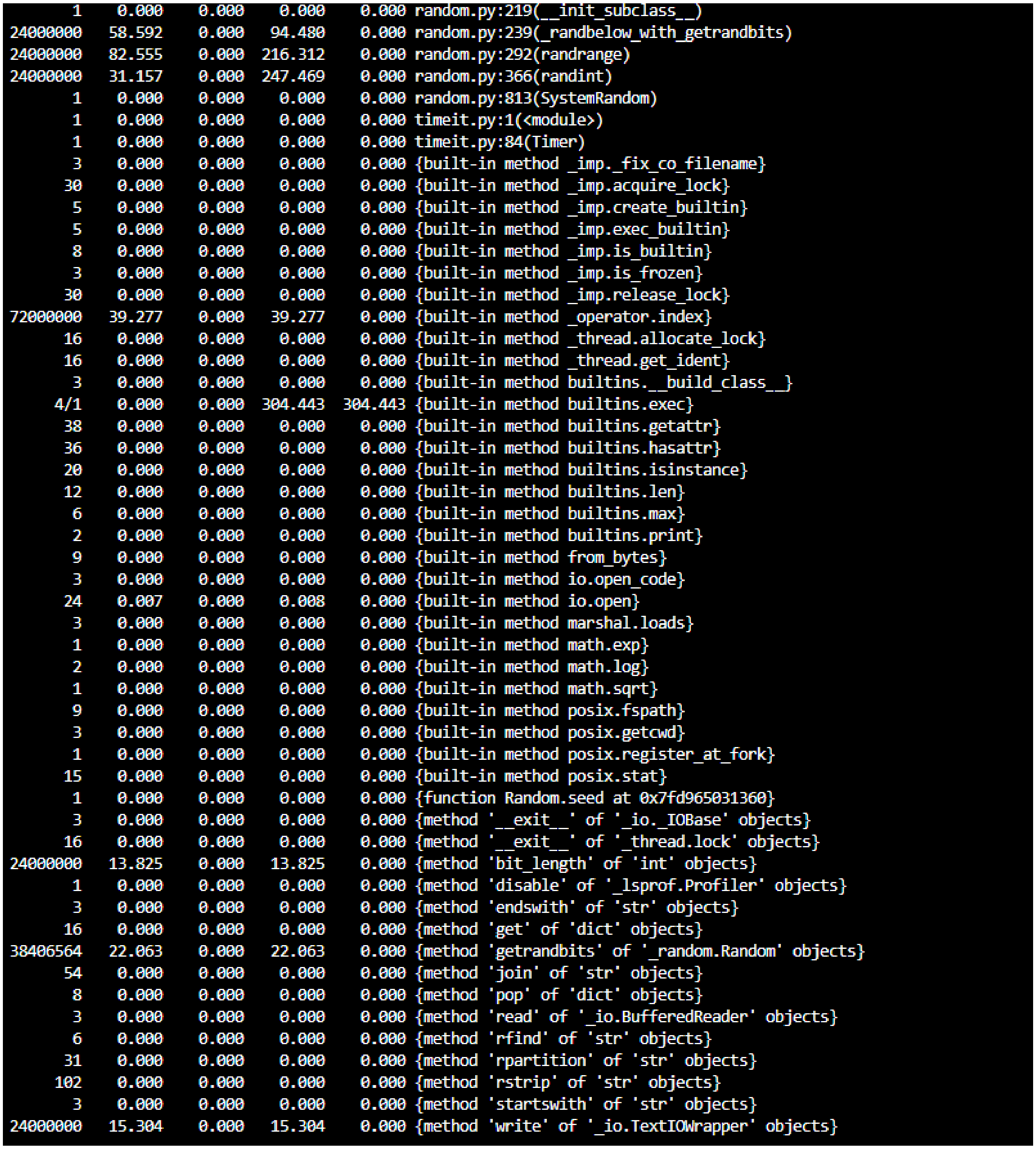


```
punyajamishra@LAPTOP-786BHK21:~/4350$ python3 A4_benchmark_1mb.py
Creation 24 1 MB file and writing in them....
Creation and writing into 24s 1 MB takes 20.316339900004095  time
punyajamishra@LAPTOP-786BHK21:~/4350$ 
```

CPROFILE – I did this on the multiple small file, and let me tell you, of course it took time because it was getting all details and all. And I did not have the guts to try on 100MB. But I did, it’s the next set of screenshots.

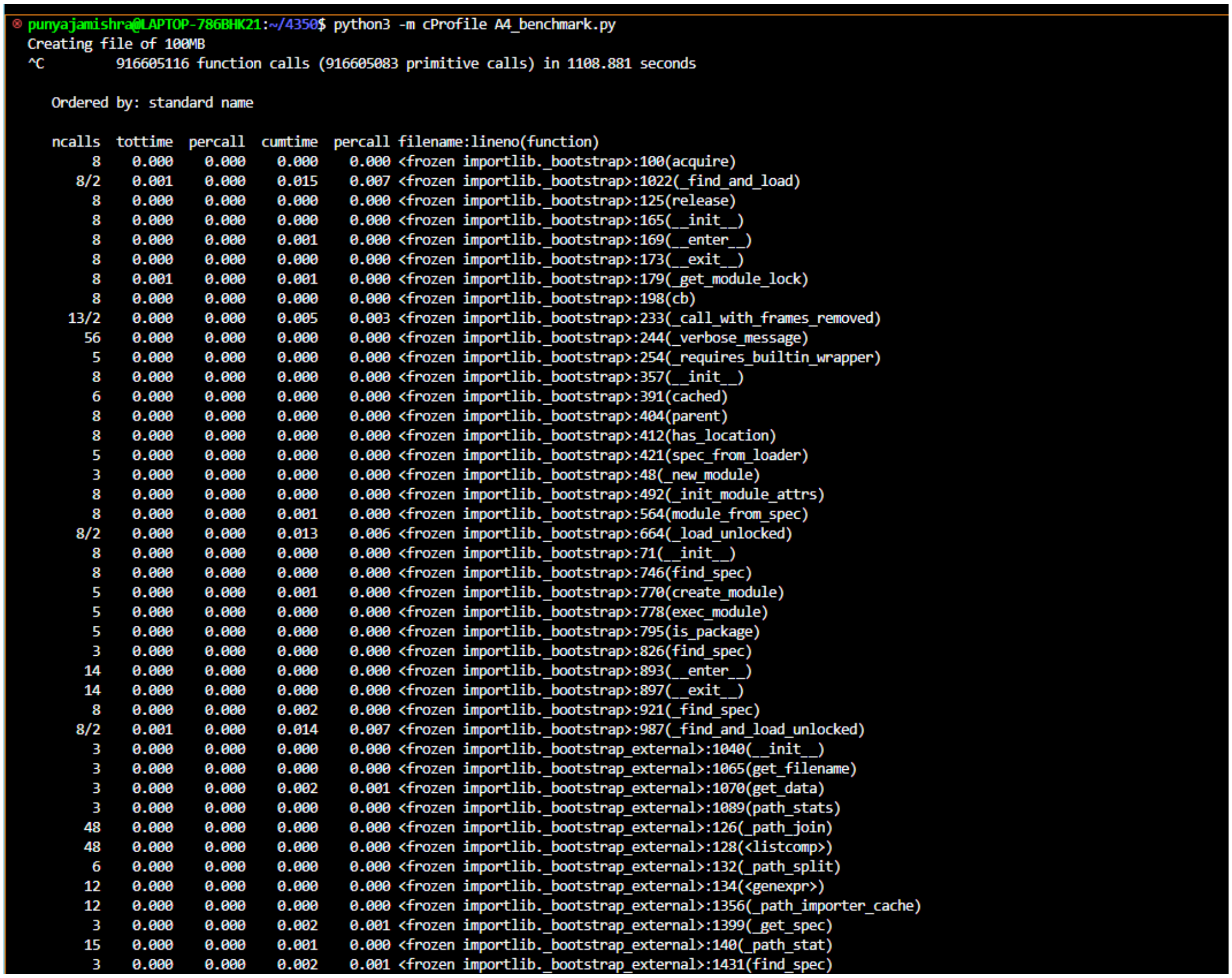


```
punyajamishra@LAPTOP-786BHK21:~/4350$ python3 -m cProfile A4_benchmark_1mb.py
Creation 24 1 MB file and writing in them....
cprofiling...
         230407662 function calls (230407629 primitive calls) in 304.443 seconds

   Ordered by: standard name

   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
        8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:100(acquire)
      8/2    0.000    0.000    0.002    0.001 <frozen importlib._bootstrap>:1022(_find_and_load)
        8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:125(release)
        8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:165(__init__)
        8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:169(__enter__)
        8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:173(__exit__)
        8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:179(_get_module_lock)
        8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:198(cb)
     13/2    0.000    0.000    0.001    0.001 <frozen importlib._bootstrap>:233(_call_with_frames_removed)
       56    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:244(_verbose_message)
        5    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:254(_requires_builtin_wrapper)
        8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:357(__init__)
        6    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:391(cached)
        8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:404(parent)
        8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:412(has_location)
        5    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:421(spec_from_loader)
        3    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:48(_new_module)
        8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:492(_init_module_attrs)
        8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:564(module_from_spec)
      8/2    0.000    0.000    0.002    0.001 <frozen importlib._bootstrap>:664(_load_unlocked)
        8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:71(__init__)
        8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:746(find_spec)
        5    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:770(create_module)
        5    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:778(exec_module)
        5    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:795(is_package)
        3    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:826(find_spec)
       14    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:893(__enter__)
       14    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:897(__exit__)
        8    0.000    0.000    0.001    0.000 <frozen importlib._bootstrap>:921(_find_spec)
      8/2    0.000    0.000    0.002    0.001 <frozen importlib._bootstrap>:987(_find_and_load_unlocked)
        3    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:1040(__init__)
        3    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:1065(get_filename)
        3    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:1070(get_data)
        3    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:1089(path_stats)
       48    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:126(_path_join)
       48    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:128(<listcomp>)
        6    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:132(_path_split)
       12    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:134(<genexpr>)
       12    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:1356(_path_importer_cache)
        3    0.000    0.000    0.001    0.000 <frozen importlib._bootstrap_external>:1399(_get_spec)
       15    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:140(_path_stat)
        3    0.000    0.000    0.001    0.000 <frozen importlib._bootstrap_external>:1431(find_spec)
        3    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:150(_path_is_mode_type)
        3    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:1531(_get_spec)
        9    0.000    0.000    0.001    0.000 <frozen importlib._bootstrap_external>:1536(find_spec)
        3    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:159(_path_isfile)
```



```
       1    0.000    0.000    0.000    0.000 random.py:219(__init_subclass__)
24000000   58.592    0.000   94.480    0.000 random.py:239(_randbelow_with_getrandbits)
24000000   82.555    0.000  216.312    0.000 random.py:292(randrange)
24000000   31.157    0.000  247.469    0.000 random.py:366(randint)
       1    0.000    0.000    0.000    0.000 random.py:813(SystemRandom)
       1    0.000    0.000    0.000    0.000 timeit.py:1(<module>)
       1    0.000    0.000    0.000    0.000 timeit.py:84(Timer)
       3    0.000    0.000    0.000    0.000 {built-in method _imp._fix_co_filename}
      30    0.000    0.000    0.000    0.000 {built-in method _imp.acquire_lock}
       5    0.000    0.000    0.000    0.000 {built-in method _imp.create_builtin}
       5    0.000    0.000    0.000    0.000 {built-in method _imp.exec_builtin}
       8    0.000    0.000    0.000    0.000 {built-in method _imp.is_builtin}
       3    0.000    0.000    0.000    0.000 {built-in method _imp.is_frozen}
      30    0.000    0.000    0.000    0.000 {built-in method _imp.release_lock}
72000000   39.277    0.000   39.277    0.000 {built-in method _operator.index}
      16    0.000    0.000    0.000    0.000 {built-in method _thread.allocate_lock}
      16    0.000    0.000    0.000    0.000 {built-in method _thread.get_ident}
       3    0.000    0.000    0.000    0.000 {built-in method builtins.__build_class__}
     4/1    0.000    0.000  304.443  304.443 {built-in method builtins.exec}
      38    0.000    0.000    0.000    0.000 {built-in method builtins.getattr}
      36    0.000    0.000    0.000    0.000 {built-in method builtins.hasattr}
      20    0.000    0.000    0.000    0.000 {built-in method builtins.isinstance}
      12    0.000    0.000    0.000    0.000 {built-in method builtins.len}
       6    0.000    0.000    0.000    0.000 {built-in method builtins.max}
       2    0.000    0.000    0.000    0.000 {built-in method builtins.print}
       9    0.000    0.000    0.000    0.000 {built-in method from_bytes}
       3    0.000    0.000    0.000    0.000 {built-in method io.open_code}
      24    0.007    0.000    0.008    0.000 {built-in method io.open}
       3    0.000    0.000    0.000    0.000 {built-in method marshal.loads}
       1    0.000    0.000    0.000    0.000 {built-in method math.exp}
       2    0.000    0.000    0.000    0.000 {built-in method math.log}
       1    0.000    0.000    0.000    0.000 {built-in method math.sqrt}
       9    0.000    0.000    0.000    0.000 {built-in method posix.fspath}
       3    0.000    0.000    0.000    0.000 {built-in method posix.getcwd}
       1    0.000    0.000    0.000    0.000 {built-in method posix.register_at_fork}
      15    0.000    0.000    0.000    0.000 {built-in method posix.stat}
       1    0.000    0.000    0.000    0.000 {function Random.seed at 0x7fd965031360}
       3    0.000    0.000    0.000    0.000 {method '__exit__' of '_io._IOBase' objects}
      16    0.000    0.000    0.000    0.000 {method '__exit__' of '_thread.lock' objects}
24000000   13.825    0.000   13.825    0.000 {method 'bit_length' of 'int' objects}
       1    0.000    0.000    0.000    0.000 {method 'disable' of '_lsprof.Profiler' objects}
       3    0.000    0.000    0.000    0.000 {method 'endswith' of 'str' objects}
      16    0.000    0.000    0.000    0.000 {method 'get' of 'dict' objects}
38406564   22.063    0.000   22.063    0.000 {method 'getrandbits' of '_random.Random' objects}
      54    0.000    0.000    0.000    0.000 {method 'join' of 'str' objects}
       8    0.000    0.000    0.000    0.000 {method 'pop' of 'dict' objects}
       3    0.000    0.000    0.000    0.000 {method 'read' of '_io.BufferedReader' objects}
       6    0.000    0.000    0.000    0.000 {method 'rfind' of 'str' objects}
      31    0.000    0.000    0.000    0.000 {method 'rpartition' of 'str' objects}
     102    0.000    0.000    0.000    0.000 {method 'rstrip' of 'str' objects}
       3    0.000    0.000    0.000    0.000 {method 'startswith' of 'str' objects}
24000000   15.304    0.000   15.304    0.000 {method 'write' of '_io.TextIOWrapper' objects}
```

SO, I did try profiling for 100MB and as you can see it has been running for minutes! And I got scared of my laptop blowing up so I stopped but there:



```
⊗ punyajamishra@LAPTOP-786BHK21:~/4350$ python3 -m cProfile A4_benchmark.py
  Creating file of 100MB
  ^C         916605116 function calls (916605083 primitive calls) in 1108.881 seconds

     Ordered by: standard name

     ncalls  tottime  percall  cumtime  percall filename:lineno(function)
          8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:100(acquire)
        8/2    0.001    0.000    0.015    0.007 <frozen importlib._bootstrap>:1022(_find_and_load)
          8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:125(release)
          8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:165(__init__)
          8    0.000    0.000    0.001    0.000 <frozen importlib._bootstrap>:169(__enter__)
          8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:173(__exit__)
          8    0.001    0.000    0.001    0.000 <frozen importlib._bootstrap>:179(_get_module_lock)
          8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:198(cb)
       13/2    0.000    0.000    0.005    0.003 <frozen importlib._bootstrap>:233(_call_with_frames_removed)
         56    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:244(_verbose_message)
          5    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:254(_requires_builtin_wrapper)
          8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:357(__init__)
          6    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:391(cached)
          8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:404(parent)
          8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:412(has_location)
          5    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:421(spec_from_loader)
          3    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:48(_new_module)
          8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:492(_init_module_attrs)
          8    0.000    0.000    0.001    0.000 <frozen importlib._bootstrap>:564(module_from_spec)
        8/2    0.000    0.000    0.013    0.006 <frozen importlib._bootstrap>:664(_load_unlocked)
          8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:71(__init__)
          8    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:746(find_spec)
          5    0.000    0.000    0.001    0.000 <frozen importlib._bootstrap>:770(create_module)
          5    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:778(exec_module)
          5    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:795(is_package)
          3    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:826(find_spec)
         14    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:893(__enter__)
         14    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap>:897(__exit__)
          8    0.000    0.000    0.002    0.000 <frozen importlib._bootstrap>:921(_find_spec)
        8/2    0.001    0.000    0.014    0.007 <frozen importlib._bootstrap>:987(_find_and_load_unlocked)
          3    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:1040(__init__)
          3    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:1065(get_filename)
          3    0.000    0.000    0.002    0.001 <frozen importlib._bootstrap_external>:1070(get_data)
          3    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:1089(path_stats)
         48    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:126(_path_join)
         48    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:128(<listcomp>)
          6    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:132(_path_split)
         12    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:134(<genexpr>)
         12    0.000    0.000    0.000    0.000 <frozen importlib._bootstrap_external>:1356(_path_importer_cache)
          3    0.000    0.000    0.002    0.001 <frozen importlib._bootstrap_external>:1399(_get_spec)
         15    0.000    0.000    0.001    0.000 <frozen importlib._bootstrap_external>:140(_path_stat)
          3    0.000    0.000    0.002    0.001 <frozen importlib._bootstrap_external>:1431(find_spec)
```