

# COEN Homework 1

## System Vs OS Virtualization

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### 1. Environment Setup:

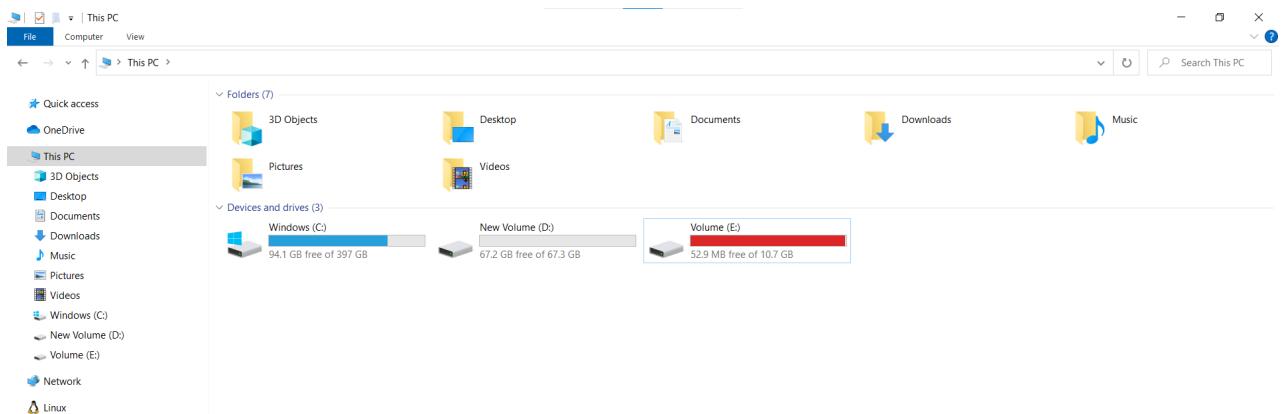
#### a. Installation of Ubuntu on Windows:

The Ubuntu image is downloaded from the following link:

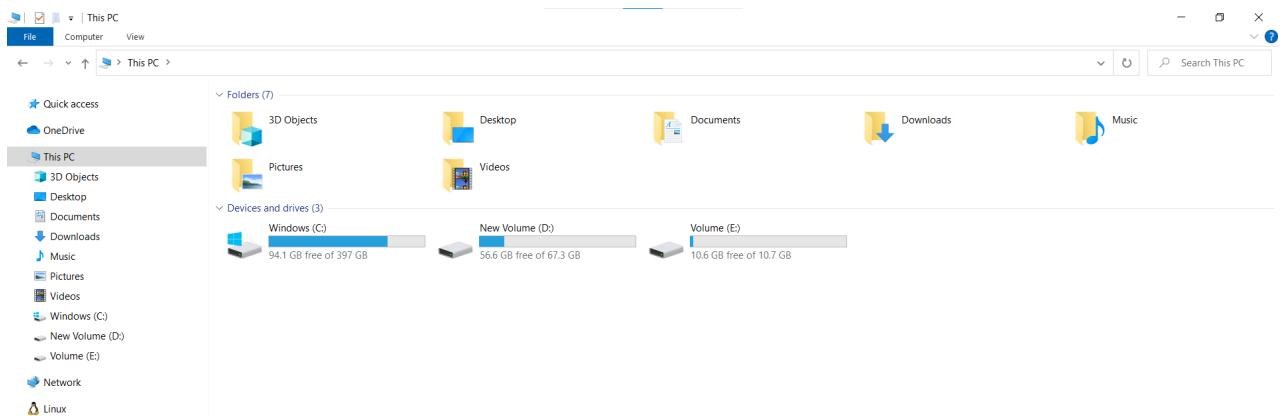
<https://releases.ubuntu.com/20.04.5/>

#### b. Installation of QEMU on Windows:

1. Downloaded QEMU from <https://qemu.weilnetz.de/w64/>.
2. Created a partition on my computer called drive D:.

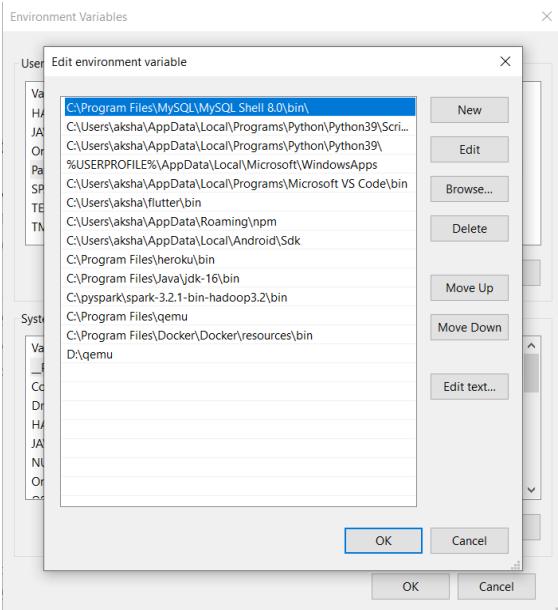


#### 3. Installed QEMU into drive D:..



#### 4. Added QEMU path into the environment variables.

5. Opened command prompt as administrator.



6. Ran the following commands:

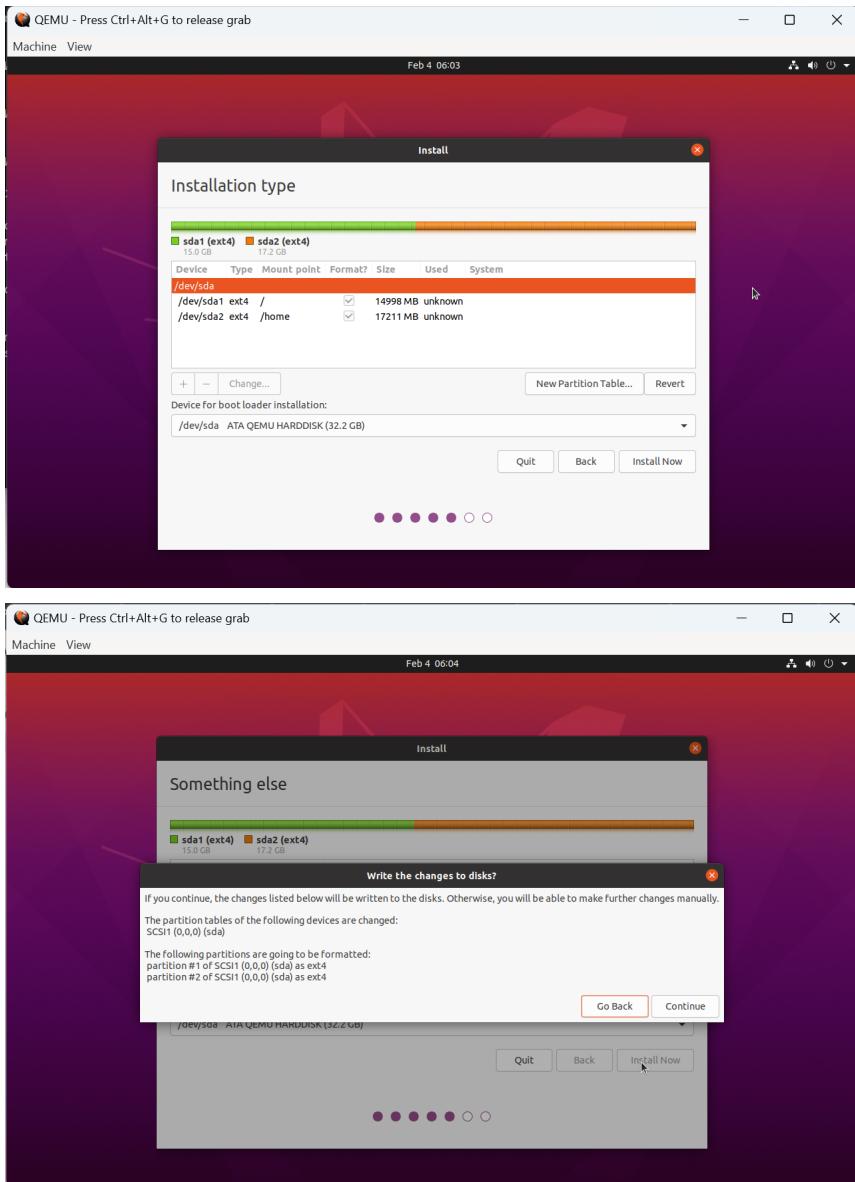
D:

```
cd \qemu
qemu-img create -f qcow2 ubuntu20.img 30G
qemu-system-x86_64.exe -m 1G -smp 2 -boot order=dc -hda
ubuntu20.img -cdrom "e:\ubuntu-20.04.3-desktop-amd64.iso"
```

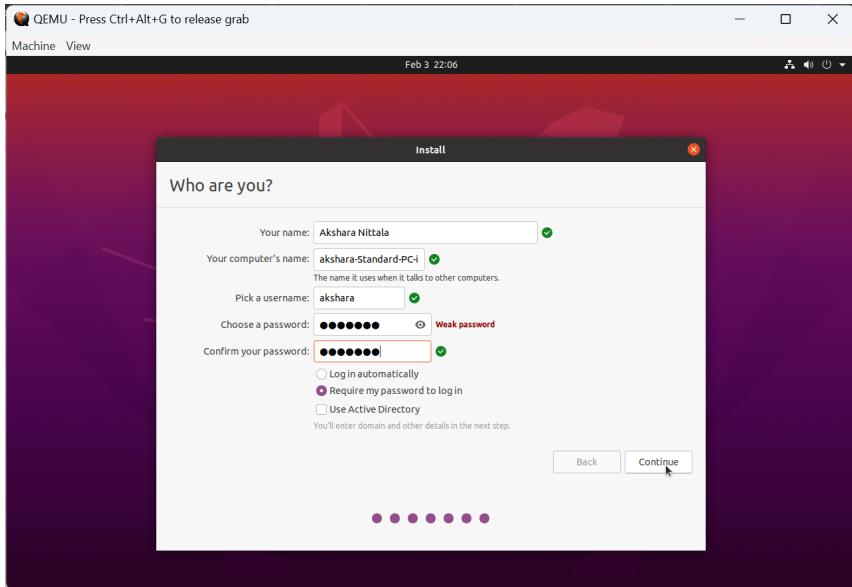
```
C:\Windows\System32>D:
D:>cd \qemu
D:\qemu>qemu-img create -f qcow2 ubuntu20.img 30G
Formatting 'ubuntu20.img', fmt=qcow2 cluster_size=65536 extended_l2=off compression_type=zlib size=32212254720 lazy_refcounts=off refcount_bits=16
D:\qemu>qemu-system-x86_64.exe -m 4G -smp 2 -boot order=dc -hda ubuntu20.img -cdrom "D:\ubuntu-20.04.5-desktop-amd64.iso"
(qemu:12116): Gtk-WARNING **: 21:51:06.795: Could not load a pixbuf from icon theme.
This may indicate that pixbuf loaders or the mime database could not be found.
```

7. After this the Ubuntu VM opens in QEMU for installation.

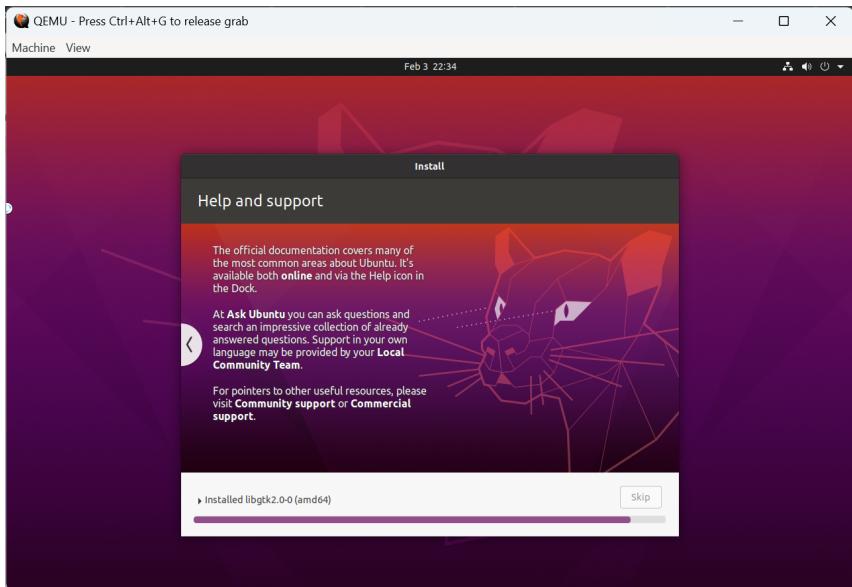
Below, 2 partitions were created for the installation of Ubuntu.



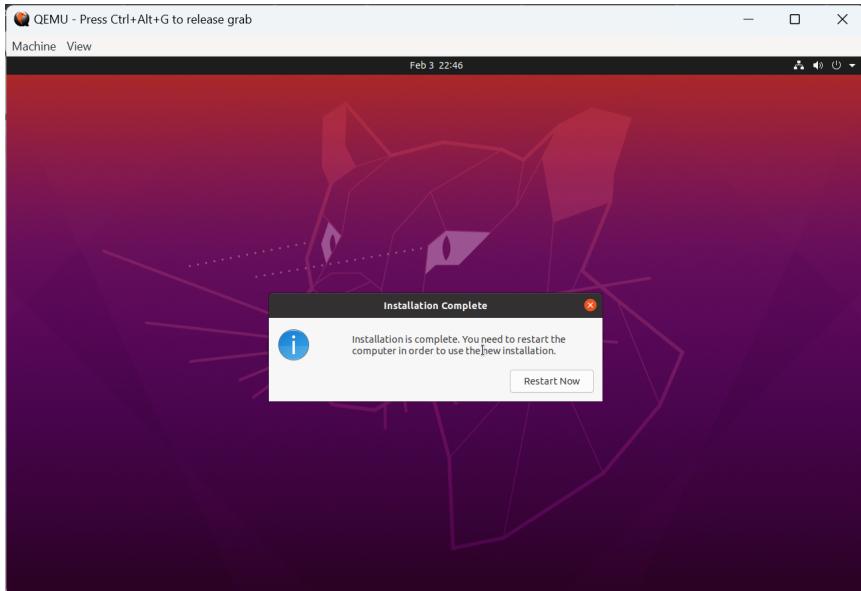
Below, the dialog for creation of a default user is opened.



After clicking continue, the installation begins.



The installation is complete. We can close the dialog and go back to the command prompt.

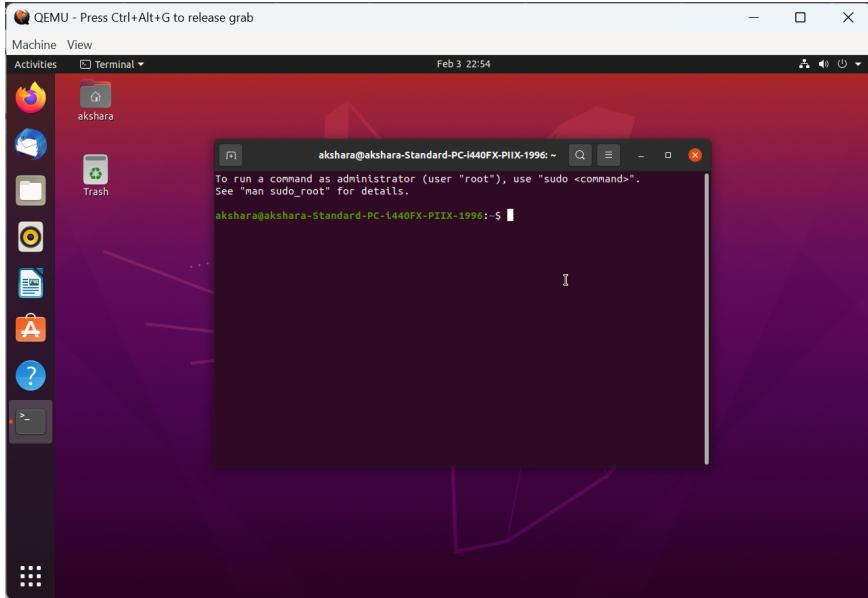


8. We store the downloaded Ubuntu image in the D: drive.
9. To run the Ubuntu terminal we run the following command:

```
qemu-system-x86_64.exe -m 4G -smp 2 -boot order=dc -hda
ubuntu20.img -cdrom "D:\ubuntu-20.04.5-desktop-amd64.iso"
```

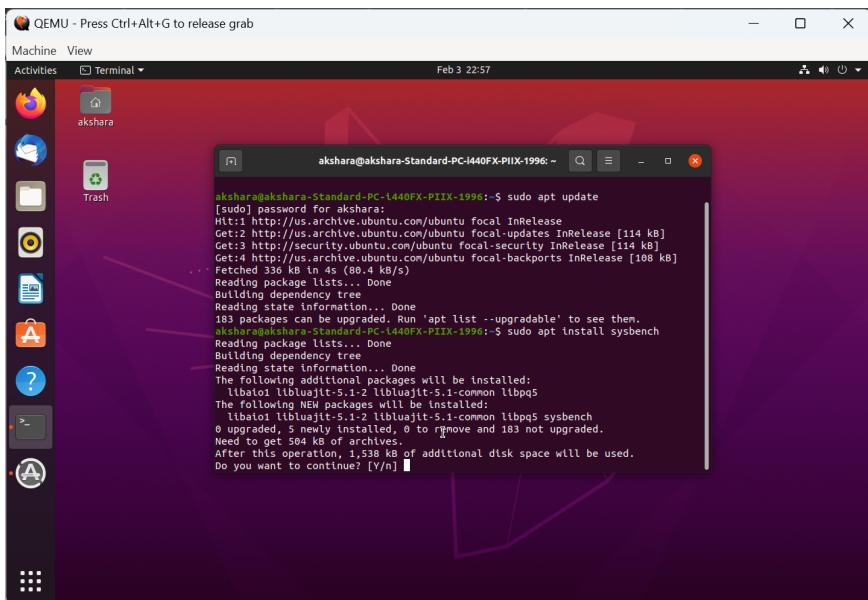
```
C:\Windows\System32>D:  
D:>cd \qemu  
  
D:\qemu>qemu-img create -f qcow2 ubuntu20.img 30G  
Formatting 'ubuntu20.img', fmt=qcow2 cluster_size=65536 extended_l2=off compression_type=zlib size=32212254720 lazy_refcounts=off refcount_bits=16  
  
D:\qemu>qemu-system-x86_64.exe -m 4G -smp 2 -boot order=dc -hda ubuntu20.img -cdrom "D:\ubuntu-20.04.5-desktop-amd64.iso"  
  
(qemu:12116): Gtk-WARNING **: 21:51:06.795: Could not load a pixbuf from icon theme.  
This may indicate that pixbuf loaders or the mime database could not be found.  
  
D:\qemu>qemu-system-x86_64.exe -m 4G -smp 2 -boot order=dc -hda ubuntu20.img  
  
(qemu:10864): Gtk-WARNING **: 22:48:45.074: Could not load a pixbuf from icon theme.  
This may indicate that pixbuf loaders or the mime database could not be found.
```

10. The Ubuntu VM starts. After logging in, I opened a terminal.



11. The following commands were run to install sysbench:

```
sudo apt update  
sudo apt install sysbench
```

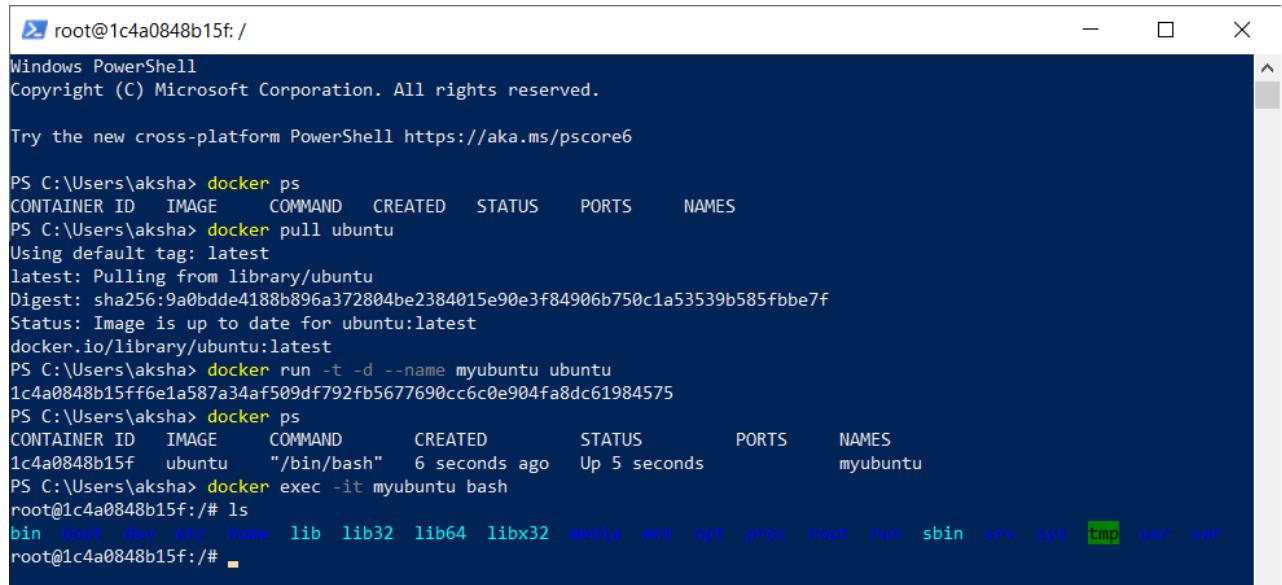


12. With this, the installation of Ubuntu in QEMU has been completed.

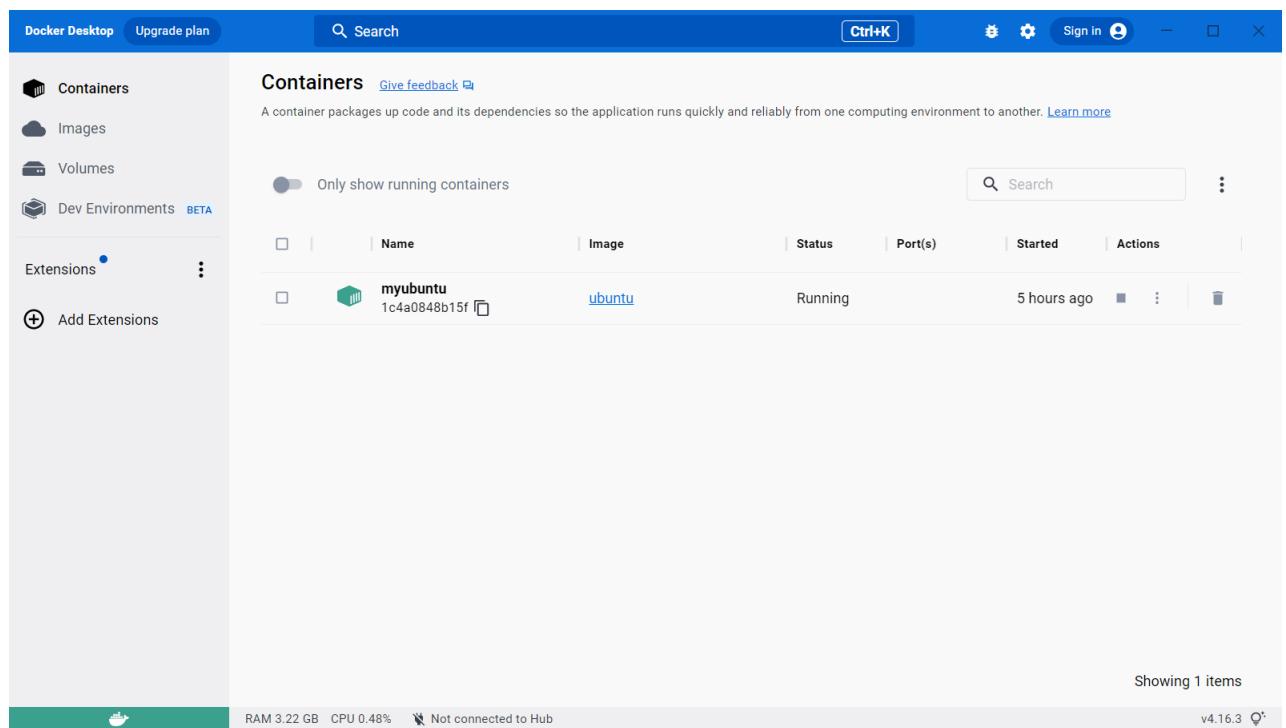
c. Installation of Docker on Windows:

1. Docker desktop is installed from the following link:  
<https://docs.docker.com/desktop/install/windows-install/>
2. Then we go to Windows Powershell type the following commands:  
docker ps  
docker pull ubuntu

```
docker run -t -d -name ubuntu ubuntu (creates a container)  
docker exec -it ubuntu bash (starts ubuntu bash on that container)
```



```
PS C:\Users\aksha> docker ps  
CONTAINER ID IMAGE COMMAND CREATED STATUS PORTS NAMES  
PS C:\Users\aksha> docker pull ubuntu  
Using default tag: latest  
latest: Pulling from library/ubuntu  
Digest: sha256:9a0bdde4188b896a372804be2384015e90e3f84906b750c1a53539b585fbbe7f  
Status: Image is up to date for ubuntu:latest  
docker.io/library/ubuntu:latest  
PS C:\Users\aksha> docker run -t -d --name myubuntu ubuntu  
1c4a0848b15ff6e1a587a34af509df792fb5677690cc6c0e904fa8dc61984575  
PS C:\Users\aksha> docker ps  
CONTAINER ID IMAGE COMMAND CREATED STATUS PORTS NAMES  
1c4a0848b15f ubuntu "/bin/bash" 6 seconds ago Up 5 seconds myubuntu  
PS C:\Users\aksha> docker exec -it myubuntu bash  
root@1c4a0848b15f:/# ls  
bin boot dev etc home lib lib32 lib64 libx32 media mnt opt proc root run sbin srv sys tmp usr var  
root@1c4a0848b15f:/#
```



3. The following commands are run to install sysbench:  
`apt update`  
`apt install sysbench`
4. With this, the installation of Ubuntu in Docker has been completed.

## 1) CPU Testing

For CPU testing, I will be running 3 test cases to evaluate CPU performance between Docker and QEMU.

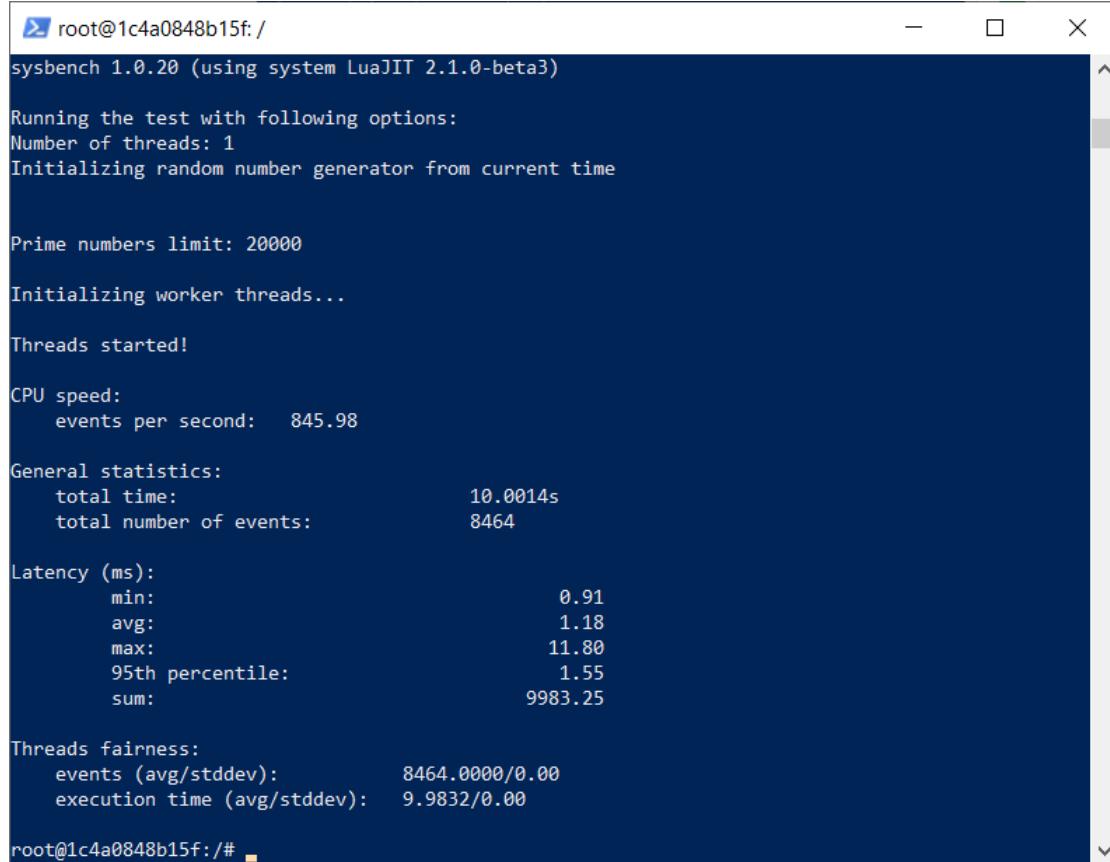
The sysbench command used for the related test cases is:

```
sysbench cpu --cpu-max-prime={some_value}  
--num-threads={some_value} --time= {some_value} run
```

### a) Docker Ubuntu VM:

1. sysbench cpu -threads=1 -cpu-max-prime=20000 -time=10 run

Output:



The screenshot shows a terminal window with the following output:

```
root@1c4a0848b15f:/  
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)  
Running the test with following options:  
Number of threads: 1  
Initializing random number generator from current time  
  
Prime numbers limit: 20000  
  
Initializing worker threads...  
  
Threads started!  
  
CPU speed:  
events per second: 845.98  
  
General statistics:  
total time: 10.0014s  
total number of events: 8464  
  
Latency (ms):  
min: 0.91  
avg: 1.18  
max: 11.80  
95th percentile: 1.55  
sum: 9983.25  
  
Threads fairness:  
events (avg/stddev): 8464.0000/0.00  
execution time (avg/stddev): 9.9832/0.00  
root@1c4a0848b15f:/#
```

After 5 iterations:

Iteration Number	Total Time	CPU Speed	Average Latency
1	10.0008	816.10	1.22
2	10.0006	841.06	1.19
3	10.0058	848.65	1.18
4	10.0003	803.62	1.24
5	10.0014	845.98	1.18
Minimum	10.0003	803.62	1.18
Maximum	10.0058	848.65	1.24
Average	10.00178	831.082	1.202
Standard Deviation	0.002042	17.9375	0.024

2. sysbench cpu -threads=1 -cpu-max-prime=250000 -time=10 run

#### Output:

```
Select root@1c4a0848b15f:/ 
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)
Running the test with following options:
Number of threads: 1
Initializing random number generator from current time

Prime numbers limit: 250000
Initializing worker threads...
Threads started!

CPU speed:
events per second: 30.62

General statistics:
total time: 10.0247s
total number of events: 307

Latency (ms):
min: 29.70
avg: 32.64
max: 43.23
95th percentile: 38.25
sum: 10021.48

Threads fairness:
events (avg/stddev): 307.0000/0.00
execution time (avg/stddev): 10.0215/0.00
root@1c4a0848b15f:/#
```

After 5 iterations:

Iteration Number	Total Time	CPU Speed	Average Latency
1	10.0247	30.62	32.64
2	10.0317	30.39	32.88
3	10.0053	30.33	32.90
4	10.0251	30.39	32.86
5	10.0193	30.44	32.84
Minimum	10.0053	30.33	32.64
Maximum	10.0251	30.62	32.90
Average	10.02122	30.434	32.824
Standard Deviation	0.008878	0.099318	0.094149

3. sysbench cpu -threads=1 -cpu-max-prime=500000 -time=10 run

Output:

```
root@1c4a0848b15f:/#
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 1
Initializing random number generator from current time

Prime numbers limit: 500000

Initializing worker threads...

Threads started!

CPU speed:
events per second: 11.45

General statistics:
total time: 10.0399s
total number of events: 115

Latency (ms):
min: 79.02
avg: 87.25
max: 112.49
95th percentile: 95.81
sum: 10033.83

Threads fairness:
events (avg/stddev): 115.0000/0.00
execution time (avg/stddev): 10.0338/0.00

root@1c4a0848b15f:/#
```

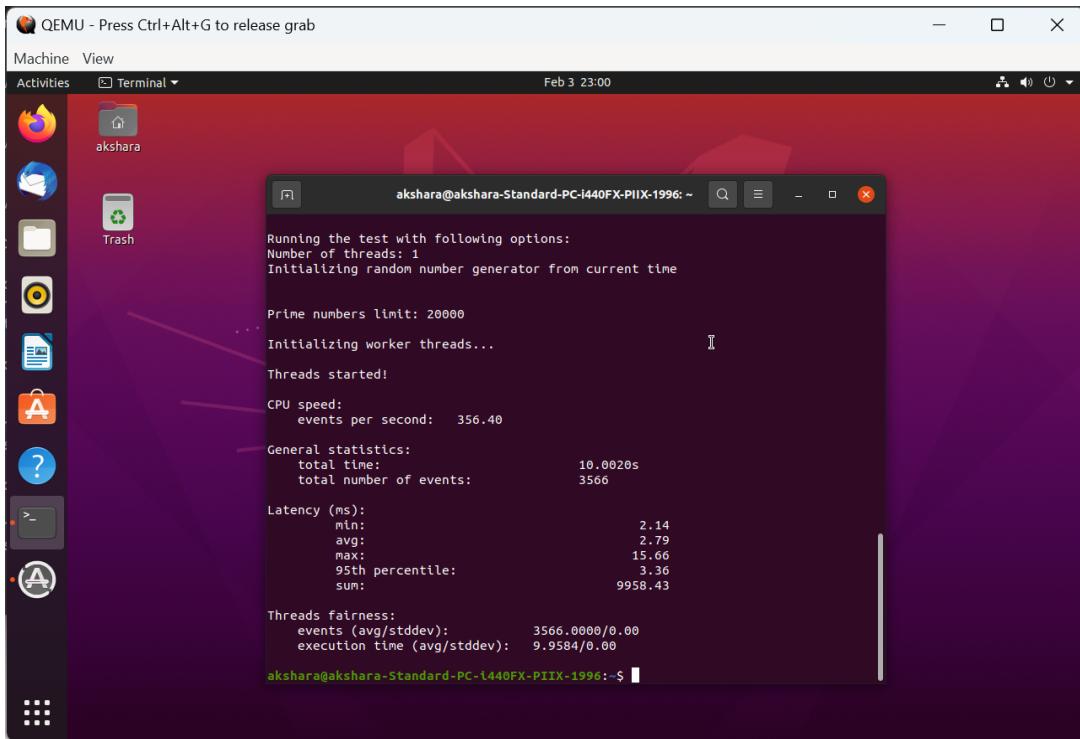
After 5 iterations:

Iteration Number	Total Time	CPU Speed	Average Latency
1	10.0399	11.45	87.25
2	10.0139	11.38	87.82
3	10.0788	11.50	86.87
4	10.0773	11.61	86.10
5	10.0423	11.45	87.23
Minimum	10.0139	11.38	86.10
Maximum	10.0788	11.61	87.82
Average	10.05044	11.478	87.054
Standard Deviation	0.02465	0.076263	0.565706

**b) QEMU Ubuntu VM:**

1. sysbench cpu -threads=1 -cpu-max-prime=20000 -time=10 run

Output:



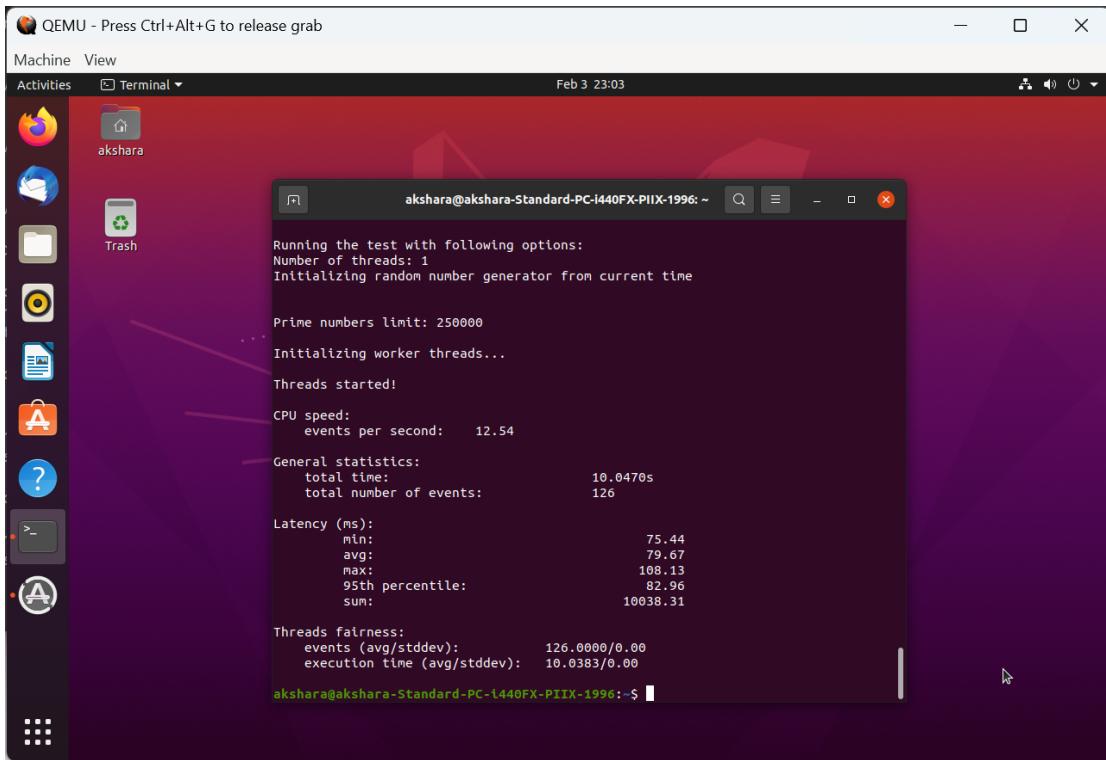
```
Running the test with following options:  
Number of threads: 1  
Initialzing random number generator from current time  
  
Prime numbers limit: 20000  
Initialzing worker threads...  
Threads started!  
CPU speed:  
    events per second: 356.40  
General statistics:  
    total time: 10.0020s  
    total number of events: 3566  
Latency (ms):  
    min: 2.14  
    avg: 2.79  
    max: 15.66  
    95th percentile: 3.36  
    sum: 9958.43  
Threads fairness:  
    events (avg/stddev): 3566.0000/0.00  
    execution time (avg/stddev): 9.9584/0.00  
akshara@akshara-Standard-PC-i440FX-PIIX-1996:~$
```

After 5 iterations:

Test Number	Total Time	CPU Speed	Average Latency
1	10.0020	350.40	2.79
2	10.0029	358.11	2.78
3	10.0019	364.04	2.74
4	10.0016	365.54	2.73
5	10.0025	364.23	2.75
Minimum	10.0016	350.40	2.73
Maximum	10.0029	365.54	2.79
Average	10.00218	360.464	2.758
Standard Deviation	0.0004621	5.649101	0.023152

2. sysbench cpu -threads=1 -cpu-max-prime=250000 -time=10 run

Output:

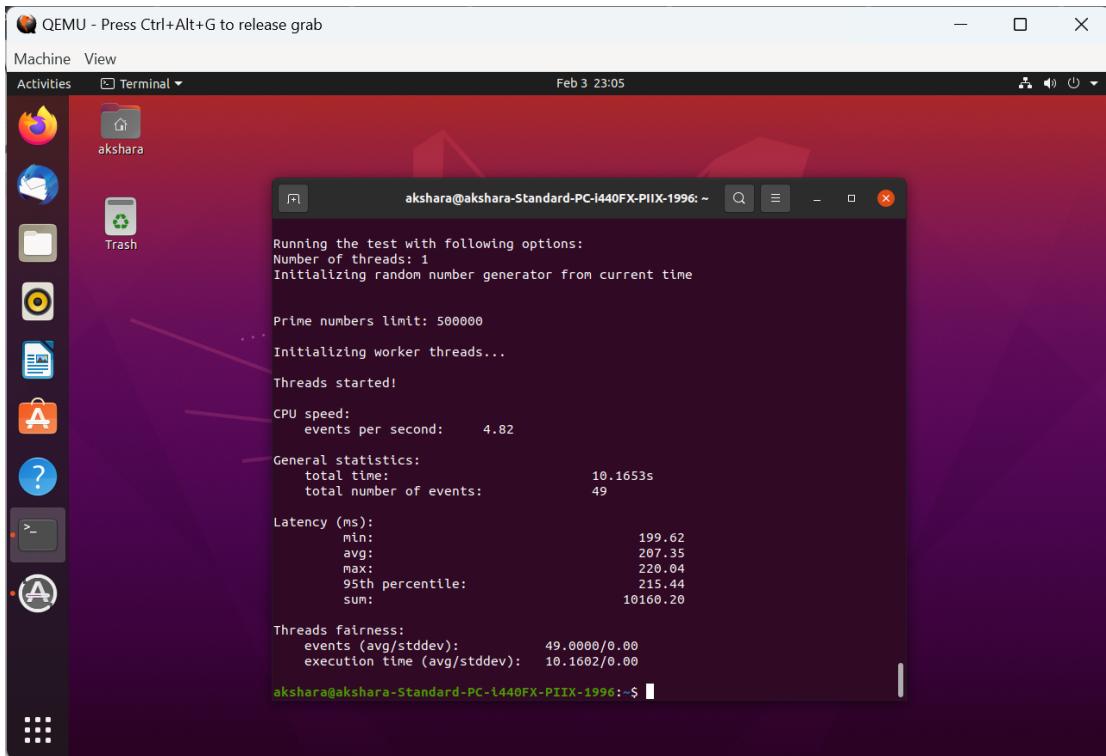


After 5 iterations:

Test Number	Total Time	CPU Speed	Average Latency
1	10.0470	12.34	79.07
2	10.0365	12.55	79.58
3	10.0495	12.04	82.98
4	10.0390	12.46	81.62
5	10.0452	12.16	80.96
Minimum	10.0365	12.04	79.07
Maximum	10.0495	12.55	82.98
Average	10.04344	12.31	80.842
Standard Deviation	0.0049066	0.1878297	1.4087498

3. sysbench cpu -threads=1 -cpu-max-prime=500000 -time=10 run

Output:



After 5 iterations:

Test Number	Total Time	CPU Speed	Average Latency
1	10.1653	4.82	267.35
2	10.0600	4.77	209.49
3	10.0950	4.69	219.65
4	10.1250	4.32	225.36
5	10.0873	4.85	250.49
Minimum	10.0600	4.32	209.49
Maximum	10.1653	4.85	467.35
Average	10.10652	4.69	234.468
Standard Deviation	0.0359522	0.192769	21.280787

**Conclusion:**

After comparing the experiment performed on Docker Ubuntu VM and QEMU Ubuntu VM, we initially see that in both the VMs the cpu speed decreases as the cpu max prime increases. The average latency increases as the cpu max prime increases.

	Docker Ubuntu VM (CPU Speed)	QEMU Ubuntu VM (CPU Speed)
Cpu max prime = 20000	831.082	360.464
Cpu max prime = 250000	30.434	12.31
Cpu max prime = 500000	11.478	4.69

When we compare the cpu speed for the same conditions, we see that QEMU Ubuntu Vm has performed much better than Docker Ubuntu VM.

## 2) File I/O Testing

For File I/O Testing, I will be testing 2 modes sysbench supports, that is:

- Sequential Rewrite (seqrewr)
- Combined Random Read/Write (rmdrw)

3 Test cases will be run to evaluate the I/O performance between Docker and QEMU.

### a) **Docker Ubuntu VM:**

#### I. Sequential Rewrite (seqrewr):

```
1. sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=1G -file-test-mode=seqrewr prepare
   sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=1G -file-test-mode=seqrewr run
   sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=1G -file-test-mode=seqrewr cleanup
```

Output:

```

root@1c4a0848b15f:/#
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 16
Initializing random number generator from current time

Extra file open flags: (none)
128 files, 8MiB each
1GiB total file size
Block size 16KiB
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing sequential rewrite test
Initializing worker threads...

Threads started!

File operations:
  reads/s:          0.00
  writes/s:         6195.36
  fsyncs/s:         7994.70

Throughput:
  read, MiB/s:      0.00
  written, MiB/s:   96.80

General statistics:
  total time:        30.1812s
  total number of events: 426263

Latency (ms):
  min:                0.00
  avg:                1.12
  max:                92.06
  95th percentile:    2.61
  sum:               479249.87

Threads fairness:
  events (avg/stddev): 26641.4375/506.28
  execution time (avg/stddev): 29.9531/0.01

root@1c4a0848b15f:/#

```

After 5 iterations:

Test Number	Read Throughput	Write Throughput	Total Time
1	0	96.80	30.1812
2	0	112.14	30.2342
3	0	120.42	30.1764
4	0	121.39	30.1684
5	0	117.78	30.1907
Minimum	0	96.80	30.1684
Maximum	0	121.39	30.2342
Average	0	113.65	30.19018
Standard Deviation	0	9.00319	0.023164

```

2. sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=2G -file-test-mode=seqrewr prepare
   sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=2G -file-test-mode=seqrewr run
   sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=2G -file-test-mode=seqrewr cleanup

```

### Output:

```

root@1c4a0848b15f: /
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 16
Initializing random number generator from current time

Extra file open flags: (none)
128 files, 16MiB each
2GiB total file size
Block size 16KiB
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing sequential rewrite test
Initializing worker threads...

Threads started!

File operations:
  reads/s:          0.00
  writes/s:        7323.77
  fsyncs/s:        9439.28

Throughput:
  read, MiB/s:      0.00
  written, MiB/s:  114.43

General statistics:
  total time:       30.1871s
  total number of events: 504018

Latency (ms):
  min:              0.00
  avg:              0.95
  max:             63.82
  95th percentile: 2.30
  sum:            479334.89

Threads fairness:
  events (avg/stddev): 31501.1250/375.57
  execution time (avg/stddev): 29.9584/0.00

root@1c4a0848b15f: #

```

After 5 iterations:

Test Number	Read Throughput	Write Throughput	Total Time
1	0	113.78	30.1812
2	0	103.60	30.1902
3	0	114.43	30.1871
4	0	117.18	30.1999

5	0	121.07	30.1847
Minimum	0	103.60	30.1812
Maximum	0	121.07	30.1999
Average	0	114.012	30.18862
Standard Deviation	0	5.80499	0.0063634

```
3. sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=4G -file-test-mode=seqrewr prepare
   sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=4G -file-test-mode=seqrewr run
   sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=4G -file-test-mode=seqrewr cleanup
```

#### Output:

```
root@1c4a0848b15f:/
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 16
Initializing random number generator from current time

Extra file open flags: (none)
128 files, 16MiB each
2GiB total file size
Block size 16KiB
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing sequential rewrite test
Initializing worker threads...

Threads started!

File operations:
  reads/s:          0.00
  writes/s:        7323.77
  fsyncs/s:        9439.28

Throughput:
  read, MiB/s:      0.00
  written, MiB/s:  114.43

General statistics:
  total time:      30.1871s
  total number of events: 504018

Latency (ms):
  min:              0.00
  avg:             0.95
  max:             63.82
  95th percentile: 2.30
  sum:            479334.89

Threads fairness:
  events (avg/stddev): 31501.1250/375.57
  execution time (avg/stddev): 29.9584/0.00

root@1c4a0848b15f:#

```

After 5 iterations:

Test Number	Read Throughput	Write Throughput	Total Time
1	0	113.54	30.1643
2	0	118.71	30.1760
3	0	114.43	30.1871
4	0	121.93	30.1625
5	0	119.89	30.1949
Minimum	0	113.54	30.1625
Maximum	0	121.93	30.1949
Average	0	117.7	30.17696
Standard Deviation	0	3.215823	0.0126091

## II. Combined Random Read/Write (rndrw)

```
1. sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=1G -file-test-mode=rndwr prepare
   sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=1G -file-test-mode=rndwr run
   sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=1G -file-test-mode=rndwr cleanup
```

Output:

```

root@1c4a0848b15f:/#
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 16
Initializing random number generator from current time

Extra file open flags: (none)
128 files, 8MiB each
1GiB total file size
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Initializing worker threads...

Threads started!

File operations:
  reads/s:          0.00
  writes/s:         7807.02
  fsyncs/s:        10057.00

Throughput:
  read, MiB/s:      0.00
  written, MiB/s:   121.98

General statistics:
  total time:       30.1755s
  total number of events: 537052

Latency (ms):
  min:                0.00
  avg:                0.89
  max:               49.79
  95th percentile:    2.57
  sum:            479342.13

Threads fairness:
  events (avg/stddev): 33565.7500/541.15
  execution time (avg/stddev): 29.9589/0.00

root@1c4a0848b15f:/#

```

After 5 iterations:

Test Number	Read Throughput	Write Throughput	Total Time
1	0	121.87	30.2158
2	0	121.98	30.1755
3	0	120.43	30.1751
4	0	114.98	30.1797
5	0	119.89	30.1816
Minimum	0	114.98	30.1751
Maximum	0	121.98	30.2158
Average	0	119.83	30.18554

Standard Deviation	0	2.556177	0.0153303
--------------------	---	----------	-----------

2. sysbench -num-threads=16 -test=fileio -time=30  
   -file-total-size=2G -file-test-mode=rndwr prepare  
   sysbench -num-threads=16 -test=fileio -time=30  
   -file-total-size=2G -file-test-mode=rndwr run  
   sysbench -num-threads=16 -test=fileio -time=30  
   -file-total-size=2G -file-test-mode=rndwr cleanup

### Output:

```
root@1c4a0848b15f:/  

sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)  

Running the test with following options:  

Number of threads: 16  

Initializing random number generator from current time  

Extra file open flags: (none)  

128 files, 16MiB each  

2GiB total file size  

Block size 16KiB  

Number of IO requests: 0  

Read/Write ratio for combined random IO test: 1.50  

Periodic FSYNC enabled, calling fsync() each 100 requests.  

Calling fsync() at the end of test, Enabled.  

Using synchronous I/O mode  

Doing random write test  

Initializing worker threads...  

Threads started!  

File operations:  

  reads/s:          0.00  

  writes/s:        7334.58  

  fsyncs/s:        9452.43  

Throughput:  

  read, MiB/s:      0.00  

  written, MiB/s:  114.60  

General statistics:  

  total time:       30.1833s  

  total number of events: 504681  

Latency (ms):  

  min:              0.00  

  avg:              0.95  

  max:             86.40  

  95th percentile: 2.86  

  sum:            479293.04  

Threads fairness:  

  events (avg/stddev): 31542.5625/502.80  

  execution time (avg/stddev): 29.9558/0.00  

root@1c4a0848b15f:#
```

After 5 iterations:

Test Number	Read Throughput	Write Throughput	Total Time
1	0	114.60	30.1833
2	0	126.44	30.1738

3	0	110.87	30.1995
4	0	117.91	30.1725
5	0	112.45	30.2065
Minimum	0	110.87	30.1725
Maximum	0	126.44	30.2065
Average	0	116.454	30.18712
Standard Deviation	0	5.52251	0.013672

```
3. sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=4G -file-test-mode=rndwr prepare
   sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=4G -file-test-mode=rndwr run
   sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=4G -file-test-mode=rndwr cleanup
```

### Output:

```
root@1c4a0848b15f:/
sysbench 1.0.20 (using system LuaJIT 2.1.0-beta3)
Running the test with following options:
Number of threads: 16
Initializing random number generator from current time

Extra file open flags: (none)
128 files, 32MiB each
4GiB total file size
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Initializing worker threads...

Threads started!

File operations:
  reads/s:          0.00
  writes/s:        7724.82
  fsyncs/s:       9953.81

Throughput:
  read, MiB/s:      0.00
  written, MiB/s:  120.70

General statistics:
  total time:           30.1602s
  total number of events: 531184

Latency (ms):
  min:                  0.00
  avg:                 0.90
  max:                29.27
  95th percentile:     2.57
  sum:            479270.49

Threads fairness:
  events (avg/stddev): 33199.0000/490.74
  execution time (avg/stddev): 29.9544/0.00
root@1c4a0848b15f:/#
```

After 5 iterations:

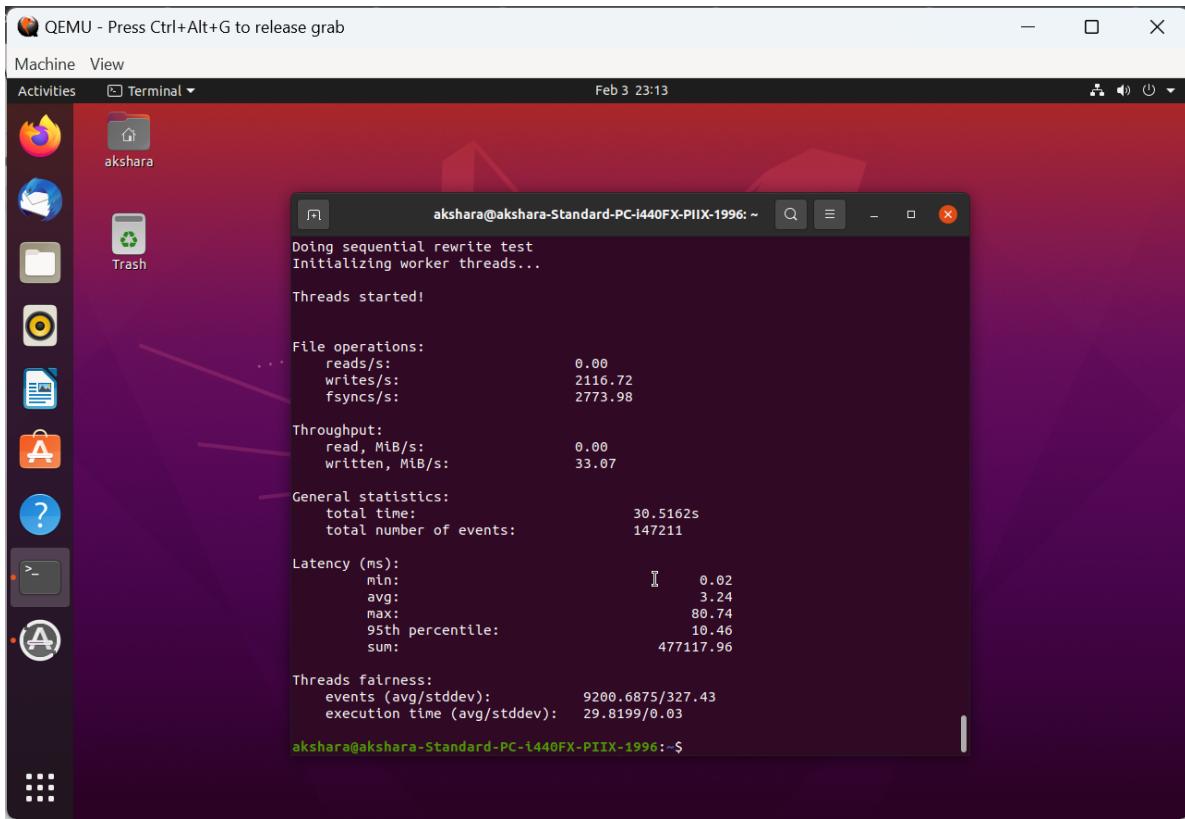
Test Number	Read Throughput	Write Throughput	Total Time
1	0	120.70	30.1602
2	0	120.96	30.1601
3	0	119.56	30.1849
4	0	116.77	30.1861
5	0	119.58	30.1816
Minimum	0	116.77	30.1601
Maximum	0	120.70	30.1861
Average	0	119.51	30.17458
Standard Deviation	0	1.485342	0.011874

b) QEMU Ubuntu VM:

I. Sequential Rewrite (seqrewr):

1. sysbench -num-threads=16 -test=fileio -time=30  
-file-total-size=1G -file-test-mode=seqrewr prepare  
sysbench -num-threads=16 -test=fileio -time=30  
-file-total-size=1G -file-test-mode=seqrewr run  
sysbench -num-threads=16 -test=fileio -time=30  
-file-total-size=1G -file-test-mode=seqrewr cleanup

Output:

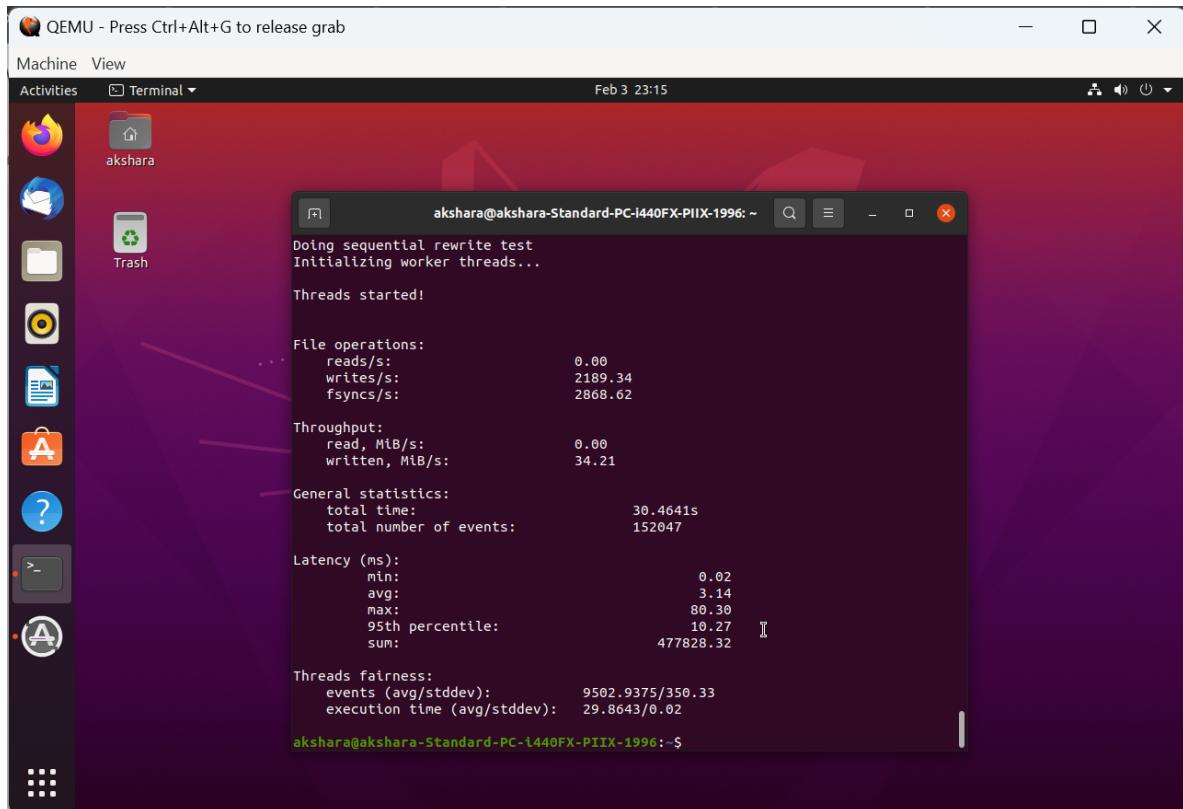


After 5 iterations:

Test Number	Read Throughput	Write Throughput	Total Time
1	0	33.07	30.5162
2	0	34.67	30.6179
3	0	32.54	30.4254
4	0	33.54	30.3957
5	0	32.97	30.3659
Minimum	0	32.54	30.3659
Maximum	0	34.67	30.6179
Average	0	33.358	30.46422
Standard Deviation	0	0.7289828	0.0918567

```
2. sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=2G -file-test-mode=seqrewr prepare
   sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=2G -file-test-mode=seqrewr run
   sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=2G -file-test-mode=seqrewr cleanup
```

### Output:



The screenshot shows a Linux desktop environment with a purple gradient background. A terminal window is open in the center, displaying the output of a sysbench sequential rewrite test. The terminal window title is "akshara@akshara-Standard-PC-i440FX-PIIX-1996: ~". The output text is as follows:

```
Doing sequential rewrite test
Initializing worker threads...
Threads started!

File operations:
  reads/s:          0.00
  writes/s:        2189.34
  fsyncs/s:       2868.62

Throughput:
  read, MiB/s:      0.00
  written, MiB/s:  34.21

General statistics:
  total time:           30.4641s
  total number of events: 152047

Latency (ms):
  min:                 0.02
  avg:                3.14
  max:                80.30
  95th percentile:    10.27
  sum:            477828.32

Threads fairness:
  events (avg/stddev): 9502.9375/350.33
  execution time (avg/stddev): 29.8643/0.02

akshara@akshara-Standard-PC-i440FX-PIIX-1996:~$
```

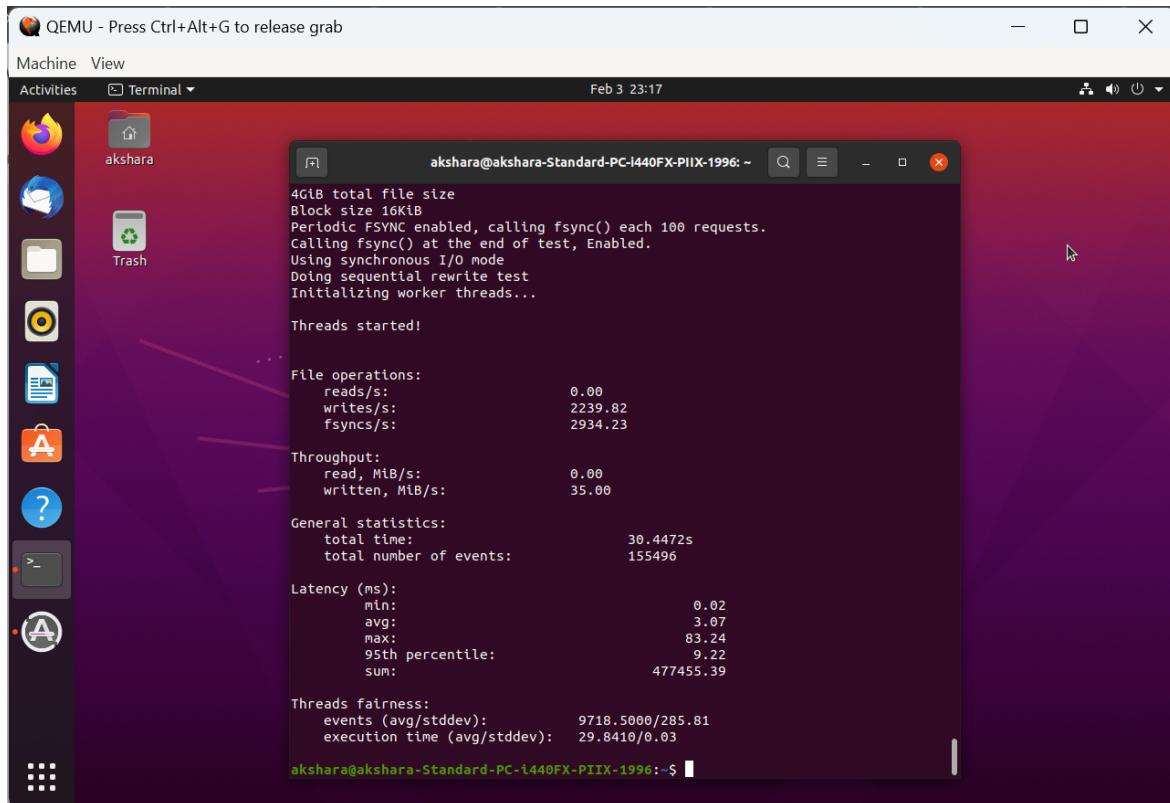
After 5 iterations:

Test Number	Read Throughput	Write Throughput	Total Time
1	0	34.21	30.4641
2	0	33.52	30.4562
3	0	32.94	30.2781
4	0	33.68	30.3842
5	0	34.17	30.2759
Minimum	0	32.94	30.2759

Maximum	0	34.21	30.4641
Average	0	33.704	30.3717
Standard Deviation	0	0.467187	0.0821862

```
3. sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=4G -file-test-mode=seqrewr prepare
   sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=4G -file-test-mode=seqrewr run
   sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=4G -file-test-mode=seqrewr cleanup
```

#### Output:



The screenshot shows a QEMU terminal window titled "akshara@akshara-Standard-PC-i440FX-PIIX-1996: ~". The terminal displays the output of a sysbench fileio test. The output includes:

- File system details: 4GiB total file size, Block size 16KiB.
- Test configuration: Periodic FSYNC enabled, calling fsync() each 100 requests, Using synchronous I/O mode, Doing sequential rewrite test.
- Initialization: Initializing worker threads.
- Threads started.
- File operations statistics:

Operation	Value
reads/s	0.00
writes/s	2239.82
fsyncs/s	2934.23

- Throughput statistics:

Operation	Value
read, MiB/s	0.00
written, MiB/s	35.00

- General statistics:

Statistic	Value
total time	30.4472s
total number of events	155496

- Latency (ms) statistics:

Statistic	Value
min	0.02
avg	3.07
max	83.24
95th percentile	9.22
sum	477455.39

- Threads fairness:

Statistic	Value
events (avg/stddev)	9718.5000/285.81
execution time (avg/stddev)	29.8410/0.03

After 5 iterations:

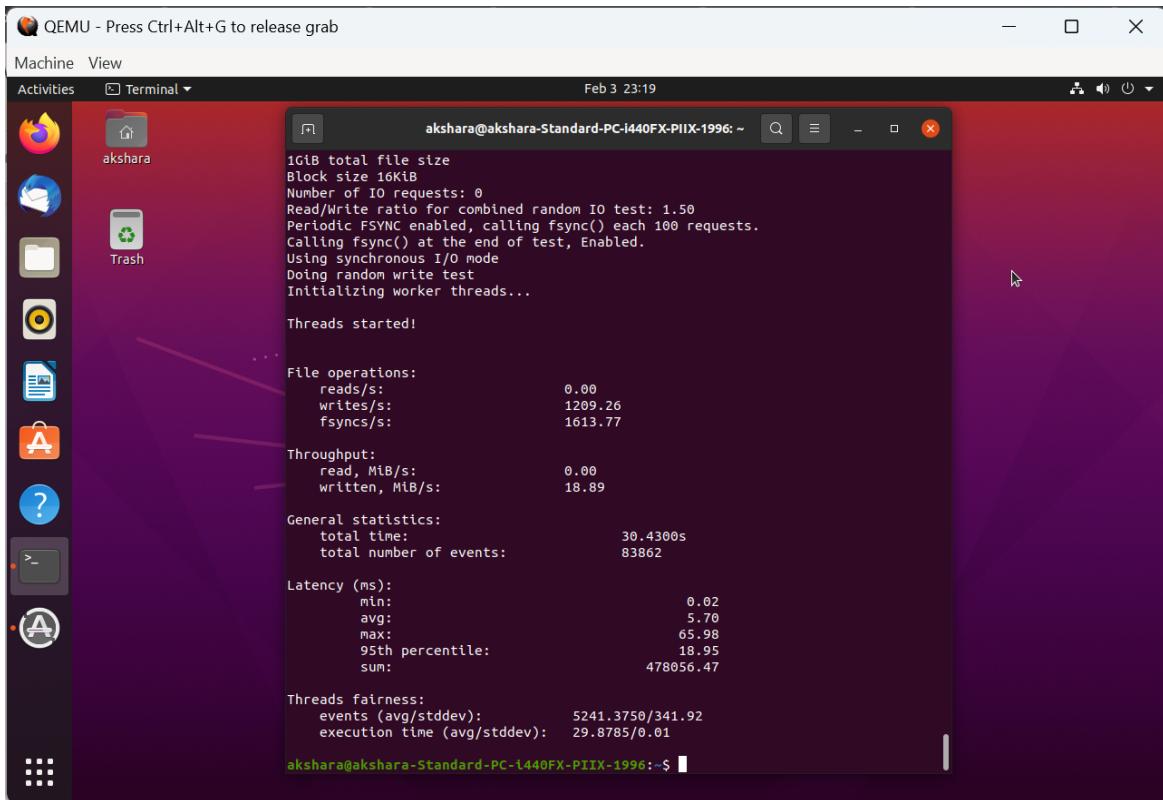
Test Number	Read Throughput	Write Throughput	Total Time
1	0	35	30.4472

2	0	34.23	30.3389
3	0	34.16	30.4125
4	0	35.12	30.4225
5	0	33.98	30.4328
Minimum	0	33.98	30.3389
Maximum	0	35.12	30.4472
Average	0	34.498	30.41078
Standard Deviation	0	0.467606	0.0377315

### III. Combined Random Read/Write (rndrw):

1. sysbench -num-threads=16 -test=fileio -time=30  
   -file-total-size=1G -file-test-mode=rndwr prepare  
   sysbench -num-threads=16 -test=fileio -time=30  
   -file-total-size=1G -file-test-mode=rndwr run  
   sysbench -num-threads=16 -test=fileio -time=30  
   -file-total-size=1G -file-test-mode=rndwr cleanup

Output:



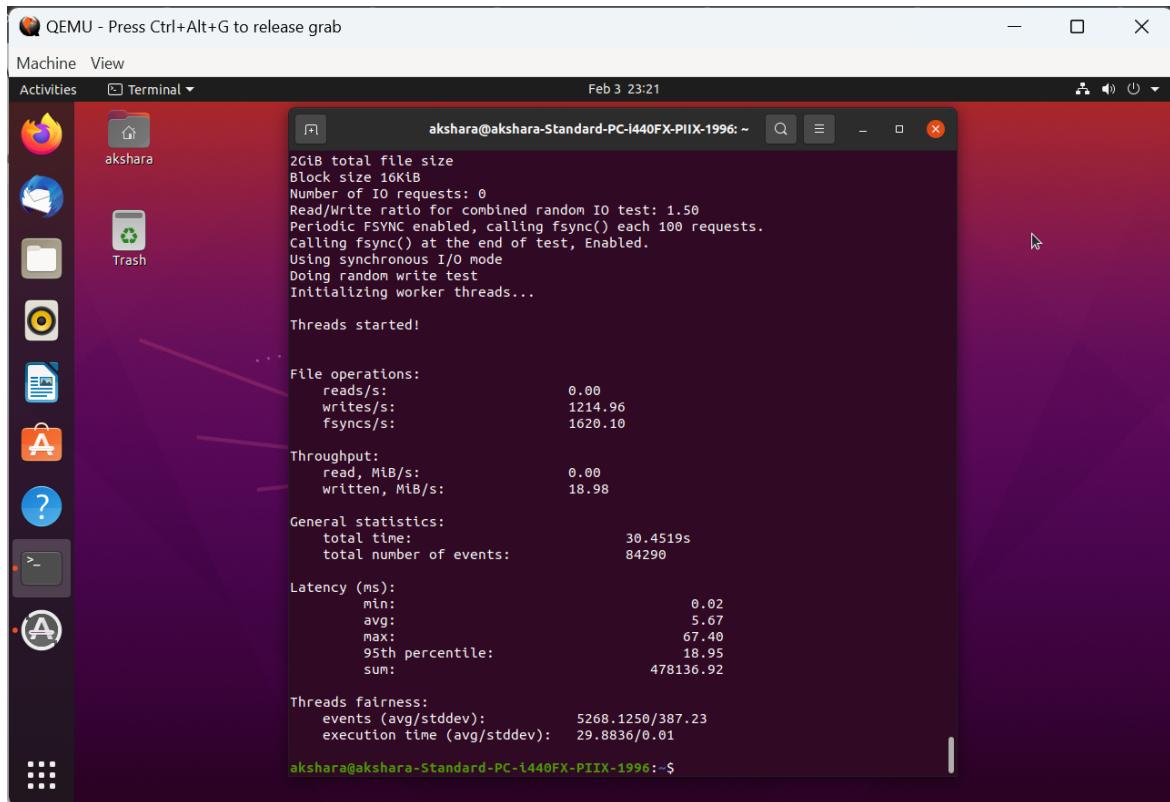
After 5 iterations:

Test Number	Read Throughput	Write Throughput	Total Time
1	0	18.89	30.4300
2	0	18.60	30.5234
3	0	18.25	30.4125
4	0	18.63	30.6327
5	0	18.85	30.4481
Minimum	0	18.25	30.6327
Maximum	0	18.89	30.4125
Average	0	18.644	30.48934
Standard Deviation	0	0.228175	0.081041

2. sysbench -num-threads=16 -test=fileio -time=30  
 -file-total-size=2G -file-test-mode=rndwr prepare

```
sysbench -num-threads=16 -test=fileio -time=30
-file-total-size=2G -file-test-mode=rndwr run
sysbench -num-threads=16 -test=fileio -time=30
-file-total-size=2G -file-test-mode=rndwr cleanup
```

### Output:



The screenshot shows a Linux desktop environment with a purple gradient background. A terminal window is open in the center, displaying the output of a sysbench fileio test. The terminal title is "akshara@akshara-Standard-PC-i440FX-PIIX-1996: ~". The output text is as follows:

```
2GiB total file size
Block size 10kB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Initializing worker threads...

Threads started!

File operations:
  reads/s:          0.00
  writes/s:        1214.96
  fsyncs/s:        1620.10

Throughput:
  read, MiB/s:      0.00
  written, MiB/s:  18.98

General statistics:
  total time:           30.4519s
  total number of events: 84290

Latency (ms):
  min:                 0.02
  avg:                 5.67
  max:                67.40
  95th percentile:    18.95
  sum:            478136.92

Threads fairness:
  events (avg/stddev): 5268.1250/387.23
  execution time (avg/stddev): 29.8836/0.01

akshara@akshara-Standard-PC-i440FX-PIIX-1996:~$
```

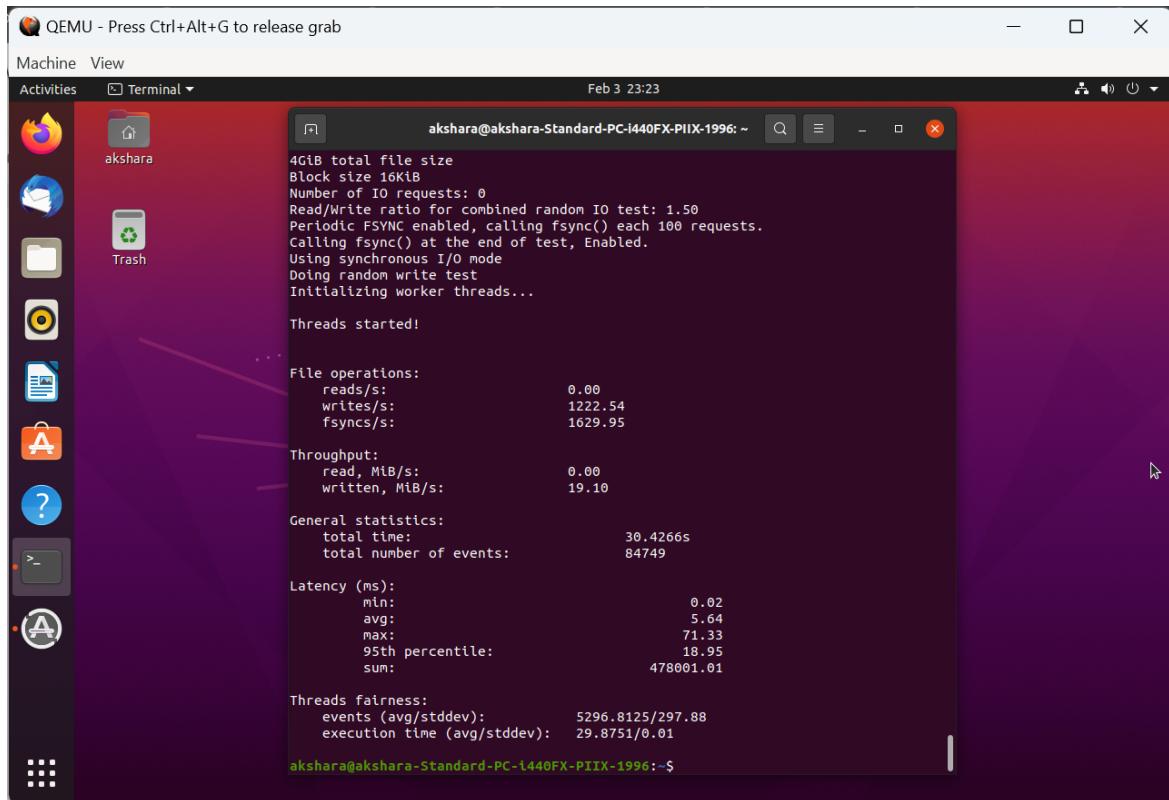
After 5 iterations:

Test Number	Read Throughput	Write Throughput	Total Time
1	0	18.98	30.4519
2	0	18.36	30.5684
3	0	18.24	30.4261
4	0	18.94	30.3957
5	0	18.96	30.3912
Minimum	0	18.24	30.3912
Maximum	0	18.98	30.5684

Average	0	18.696	30.44666
Standard Deviation	0	0.325797	0.0647202

```
3. sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=4G -file-test-mode=rndwr prepare
   sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=4G -file-test-mode=rndwr run
   sysbench -num-threads=16 -test=fileio -time=30
   -file-total-size=4G -file-test-mode=rndwr cleanup
```

### Output:



The screenshot shows a terminal window titled "akshara@akshara-Standard-PC-i440FX-PIIX-1996: ~" running on QEMU. The terminal displays the output of a sysbench fileio test. The output includes parameters like 4GiB total file size, 16 threads, and various performance metrics such as throughput (read: 0.00 MB/s, written: 19.10 MB/s), general statistics (total time: 30.4266s, total events: 84749), and latency (min: 0.02 ms, avg: 5.64 ms, max: 71.33 ms). The terminal window is part of a desktop environment with icons for a browser, file manager, and trash can.

```
4GiB total file size
Block size 16kB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Initializing worker threads...

Threads started!

File operations:
  reads/s:          0.00
  writes/s:         1222.54
  fsyncs/s:         1629.95

Throughput:
  read, MB/s:      0.00
  written, MB/s:  19.10

General statistics:
  total time:      30.4266s
  total number of events: 84749

Latency (ms):
  min:              0.02
  avg:             5.64
  max:            71.33
  95th percentile: 18.95
  sum:           478001.01

Threads fairness:
  events (avg/stddev):    5296.8125/297.88
  execution time (avg/stddev): 29.8751/0.01
akshara@akshara-Standard-PC-i440FX-PIIX-1996:~$
```

After 5 iterations:

Test Number	Read Throughput	Write Throughput	Total Time
1	0	19.10	30.4266
2	0	19.23	30.4127
3	0	18.14	30.2257

4	0	18.68	30.3587
5	0	18.54	30.3988
Minimum	0	18.14	30.2257
Maximum	0	19.23	30.4266
Average	0	18.738	30.3645
Standard Deviation	0	0.3932632	0.0730139

### **Conclusion for Sequential Rewrite:**

After comparing the experiment performed on Docker Ubuntu VM and QEMU Ubuntu VM, the conclusion is that the sequential rewrite for QEMU VM is much faster than the Docker VM.

### **Conclusion for Combined Random Read/Write:**

After comparing the experiment performed on Docker Ubuntu VM and QEMU Ubuntu VM, the conclusion is the combined random read/write for QEMU VM is 3 times better than that of the Docker VM