

CSEN 241 HW1
System vs OS Virtualization
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Computer Architecture:

This experiment ran on a computer with architecture: x86_64

Operating System:

This experiment ran on Windows 11 with [WSL2](#)

The Windows Subsystem for Linux (WSL) let developers install a Linux distribution directly on Windows, without the overhead of traditional virtual machine or dualboot setup.

Installed Linux distribution:

Ubuntu 22.04.3 LTS

```
azraelkisara@BlueBreaker:~/csen241$ lsb_release -a
No LSB modules are available.
Distributor ID: Ubuntu
Description:    Ubuntu 22.04.3 LTS
Release:        22.04
Codename:       jammy
```

Git Repository:

URL

<https://github.com/RuihaoWei95/CSE241.git>

Commit ID

e3db21d1d3186e18051990882214c61fc8a8e23d

Create QEMU disk Images:

1. Install QEMU

```
sudo apt-get install qemu-system-x86
sudo apt install qemu-utils
```

2. Download Ubuntu 20.04 Server

```
wget https://releases.ubuntu.com/focal/ubuntu-20.04.6-live-server-amd64.iso
```

3. Create QEMU disk image with qcow2 format

Run the command to create qcow2 format disk image with name ‘ubuntu.img’, storage space ‘10G’, format ‘-f qcow2’

```
sudo qemu-img create ubuntu.img 10G -f qcow2
```

4. Create QEMU disk image with raw format

Run the command to create raw format disk image with name ‘ubuntu-raw.img’, storage space ‘10G’, format ‘-f raw’

```
sudo qemu-img create ubuntu-raw.img 10G -f raw
```

5. Created Images

```
azraelkisara@BlueBreaker:~/csen241$ ls
ubuntu-20.04.6-live-server-amd64.iso  ubuntu-raw.img  ubuntu.img
```

Enable QEMU VM

1. Install VM

Run the following command to install VM with downloaded Ubuntu server iso and images we just created. Follow the instruction to finish the installation.

```
sudo qemu-system-x86_64 -hda <'Your Image Name'> -boot d -cdrom ./ubuntu-20.04.6-live-server-amd64.iso -m 2046 -boot strict=on
```

-hda <'Your Image Name'>: specifies the virtual hard disk drive

-boot d: sets the boot device order, ‘d’ means it will first try to boot from the CD-ROM drive

-cdrom ./ubuntu-20.04.6-live-server-amd64.iso: specifies an ISO image file as the CD-ROM drive content

-m 2046: sets the memory size to 2046 MB (2GB)

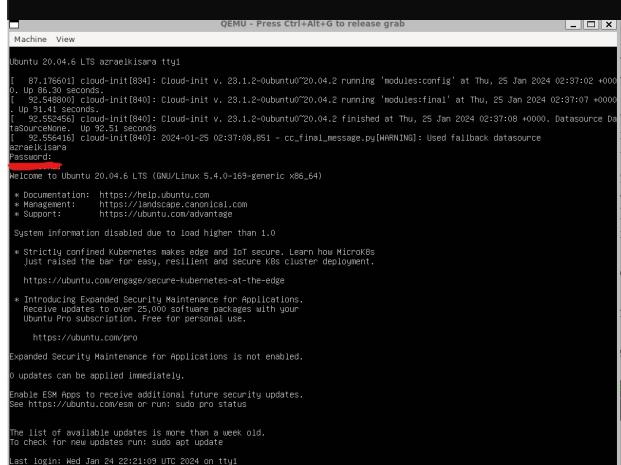
-boot strict=on: enables strict boot order

2. Enable VM

Run the following command to enable VM after the installation is succeed

```
sudo qemu-system-x86_64 -m 2046 -hda <'Your Image Name'>
```

```
azraelkisara@BlueBreaker:~/csen241$ sudo qemu-system-x86_64 -m 2046 -hda ubuntu.img
[sudo] password for azraelkisara:
```



Create Docker container Image

1. Install Docker

Follow [instruction](#) to install Docker engine on Ubuntu.

2. Create a Dockerfile

touch Dockerfile

3. Edit the Dockerfile to add sysbench to a base Ubuntu 20.04 image

FROM ubuntu:20.04

Run apt-get update && apt-get install -y sysbench

4. Build the image from edited Dockerfile

Run following command to build image from a dockerfile. Replace `<tag>` with image name.

sudo docker build -t <tag> .

```
azraelkisara@BlueBreaker:~/csen241$ sudo docker build -t docker-ubuntu .
[sudo] password for azraelkisara:
[+] Building 22.0s (6/6) FINISHED                                            docker:default
=> [internal] load build definition from Dockerfile
=> [internal] load metadata for docker.io/library/ubuntu:20.04
=> [internal] load .dockerignore
=> [internal] transfer context: 2B
=> [1/2] FROM docker.io/library/ubuntu:20.04@sha256:f2034e7195f61334e6caff6ecf2e965f92d11e888309065da85ff50c6177 5.4s
=>  resolve docker.io/library/ubuntu:20.04@sha256:f2034e7195f61334e6caff6ecf2e965f92d11e888309065da85ff50c6177 0.0s
=> sha256:f2034e7195f61334e6caff6ecf2e965f92d11e888309065da85ff50c6177 0.0s
=> sha256:bac6881102aae50ba4bcc714695b8f637e42768c7f376f374c428bab043ddc0f 424B / 424B 0.0s
=> sha256:c78999c2b36086603220655c0b079838258b8891a12ac25fc670f6ccb54229f 2.30kB / 2.30kB 0.0s
=> sha256:527f5363b98e562da03d2e0bbf86fd7c34fu87bffd9b27a3cf0a9afea2f0ee1f 27.51MB / 27.51MB 1.6s
=> extracting sha256:527f5363b98e562da03d2e0bbf86fd7c34fu87bffd9b27a3cf0a9afea2f0ee1f 3.3s
=> [2/2] RUN apt-get update && apt-get install -y sysbench 14.9s
=> exporting to image 0.0s
=> exporting layers 0.0s
=> writing image sha256:9a10ff941e9508e913edb3b6233a75b1f66a82bbc01eb4a5345ec24fe159232f 0.0s
=> naming to docker.io/library/docker-ubuntu 0.0s
```

5. Check image ID

sudo docker images

```
azraelkisara@BlueBreaker:~/csen241$ sudo docker images
REPOSITORY      TAG      IMAGE ID      CREATED      SIZE
docker-ubuntu   latest   9a10ff941e95   3 minutes ago  142MB
hello-world     latest   d2c94e258dc8   8 months ago  13.3kB
```

6. Check image history

sudo docker history <tag>

```
azraelkisara@BlueBreaker:~/csen241$ sudo docker history docker-ubuntu
IMAGE      CREATED     CREATED BY
9a10ff941e95  3 minutes ago  RUN /bin/sh -c apt-get update && apt-get...  69.3MB  buildkit.dockerfile.v0
<missing>   6 weeks ago   /bin/sh -c #(nop) CMD ["/bin/bash"]          0B
<missing>   6 weeks ago   /bin/sh -c #(nop) ADD file:5696198fbfd0#7485...  72.8MB
<missing>   6 weeks ago   /bin/sh -c #(nop) LABEL org.opencontainers...  0B
<missing>   6 weeks ago   /bin/sh -c #(nop) LABEL org.opencontainers...  0B
<missing>   6 weeks ago   /bin/sh -c #(nop) ARG LAUNCHPAD_BUILD_ARCH  0B
<missing>   6 weeks ago   /bin/sh -c #(nop) ARG RELEASE              0B
azraelkisara@BlueBreaker:~/csen241$ sudo docker run docker-ubuntu
```

7. Run the container

Run the following command to start our container

sudo docker run -it <tag> /bin/bash

-it: Run container in interactive mode with terminal

/bin/bash: Bash command to start a shell

```
azraelkisara@BlueBreaker:~/csen241$ sudo docker run -it docker-ubuntu /bin/bash
root@1ed8c35181b0:/# ls
bin  boot  dev  etc  home  lib  lib32  lib64  libx32  media  mnt  opt  proc  root  run  sbin  srv  sys  tmp  usr  var
root@1ed8c35181b0:/# sysbench --version
sysbench 1.0.18
root@1ed8c35181b0:/# sysbench cpu run
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)
```

8. Other useful docker commands

docker ps

This command list all running containers

```
azraelkisara@BlueBreaker:~/csen241$ sudo docker ps
CONTAINER ID        IMAGE               COMMAND             CREATED            STATUS              PORTS               NAMES
1ed8c35181b0        docker-ubuntu       "/bin/bash"        25 minutes ago    Up 25 minutes          beautiful_black
```

docker stop <NAME>

This command stop the container with given name

```
azraelkisara@BlueBreaker:~/csen241$ sudo docker stop beautiful_black
beautiful_black
```

QEMU Experiment

VM configuration arguments:

CPU: 2, 4
RAM: 2048, 4096

CPU 2, RAM 2048 is the basic multi-core setup. The idea is to start with a modest number of cores and amount of RAM and potentially increase to see if there is a significant improvement in performance.

1. Enable VMs:

Run following command to enable VM with different configurations. We also want to redirect port so we can SSH to VM.

```
qemu-system-x86_64 -hda <img name> -smp <cpu argument> -m <memory argument> -net user,hostfwd-tcp::<port>::22 -net nic
```

Run following command on VM to enable SSH

```
sudo apt-get update  
sudo apt-get install openssh-server  
sudo systemctl start ssh
```

Run following command on Host to SSH VM

```
ssh -p <port> user@localhost
```

2. Sysbench test cases:

- a) CPU test case 1: --cpu-max-prime=20000 --time=20 run
- b) CPU test case 2: --cpu-max-prime=80000 --time=20 run
- c) Memory test case 1: --memory-block-size=1K
- d) Memory test case 2: --memory-block-size=2K
- e) FileIO test case 1: --file-total-size=1G --file-test-mode=rndrw
- f) FileIO test case 2: --file-total-size=2G --file-test-mode=rndrw

3. Experiment with qcow2 image:

Proof of experiment

- a) cpu: 2, RAM: 2048

```
[sudo] password for azraelkisara:  
azraelkisara@BlueBreaker:~/csen241$ sudo qemu-system-x86_64 -smp 2 -m 2048 -hda ubuntu.img -net user,hostfwd=tcp::10022::22 -net nic  
[sudo] password for azraelkisara:
```

CPU test case 1

```

azraelkisara@azraelkisara:~/ | + -
0 updates can be applied immediately.

Enable ESM Apps to receive additional future security updates.
See https://ubuntu.com/esm or run: sudo pro status

The list of available updates is more than a week old.
To check for new updates run: sudo apt update
New release '22.04.3 LTS' available.
Run 'do-release-upgrade' to upgrade to it.

Last login: Fri Jan 26 00:01:56 2024
azraelkisara@azraelkisara:~$ ls
azraelkisara@azraelkisara:~$ git clone https://github.com/RuihaoWei95/CSE241.git
Cloning into 'CSE241'...
Username for 'https://github.com': RuihaoWei95
Password for 'https://RuihaoWei95@github.com':
remote: Enumerating objects: 14, done.
remote: Counting objects: 100% (14/14), done.
remote: Compressing objects: 100% (14/14), done.
remote: Total 14 (delta 1), reused 14 (delta 1), pack-reused 0
Unpacking objects: 100% (14/14), 1.76 KiB | 45.00 KiB/s, done.
azraelkisara@azraelkisara:~$ ls
CSE241
azraelkisara@azraelkisara:~$ cd CSE241/
azraelkisara@azraelkisara:~/CSE241$ ls
HW1
azraelkisara@azraelkisara:~/CSE241$ cd HW1/
azraelkisara@azraelkisara:~/CSE241/HW1$ ls
shellScripts
azraelkisara@azraelkisara:~/CSE241/HW1$ cd shellScripts/
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ ls
cpu_TestCase_1.sh
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ ./cpu_TestCase_1.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 266.75 events/sec
Test 2 of 5
Test 2 completed: 251.82 events/sec
Test 3 of 5
Test 3 completed: 253.94 events/sec
Test 4 of 5
Test 4 completed: 236.52 events/sec
Test 5 of 5
Test 5 completed: 252.33 events/sec
Performance Test Results for Events Per Second:
Average: 252.27
Minimum: 236.52
Maximum: 266.75
Standard Deviation: 9.59
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ |

```

CPU test case 2

```

azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ git pull
Username for 'https://github.com': RuihaoWei95
Password for 'https://RuihaoWei95@github.com':
remote: Enumerating objects: 15, done.
remote: Counting objects: 100% (15/15), done.
remote: Compressing objects: 100% (5/5), done.
remote: Total 9 (delta 0), reused 9 (delta 0), pack-reused 0
Unpacking objects: 100% (9/9), 1.42 KiB | 48.00 KiB/s, done.
From https://github.com/RuihaoWei95/CSE241
   c4b02b5..fb8c2ac main      -> origin/main
Updating c4b02b5..fb8c2ac
Fast-forward
HW1/shellScripts/cpu_TestCase_2.sh | 52 ++++++-----+
1 file changed, 52 insertions(+)
create mode 100644 HW1/shellScripts/cpu_TestCase_2.sh
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ ls
cpu_TestCase_1.sh  cpu_TestCase_2.sh
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ chmod +x cpu_TestCase_2.sh
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ ls
cpu_TestCase_1.sh  cpu_TestCase_2.sh
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ ./cpu_TestCase_2.sh
cpu_TestCase_2.sh: command not found
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ ./cpu_TestCase_2.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 39.68 events/sec
Test 2 of 5
Test 2 completed: 39.50 events/sec
Test 3 of 5
Test 3 completed: 40.08 events/sec
Test 4 of 5
Test 4 completed: 40.56 events/sec
Test 5 of 5
Test 5 completed: 38.49 events/sec
Performance Test Results for Events Per Second:
Average: 39.66
Minimum: 38.49
Maximum: 40.56
Standard Deviation: .68
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ |

```

Memory test case 1

```

azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ bash memory_TestCase_1.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 331.24 MiB/sec
Test 2 of 5
Test 2 completed: 330.12 MiB/sec
Test 3 of 5
Test 3 completed: 322.27 MiB/sec
Test 4 of 5
Test 4 completed: 321.20 MiB/sec
Test 5 of 5
Test 5 completed: 287.49 MiB/sec
Performance Test Results for Throughput:
Average: 318.46 MiB/sec
Minimum: 287.49 MiB/sec
Maximum: 331.24 MiB/sec
Standard Deviation: 16.002624

```

Memory test case 2

```
azraelkisara@azraelkisara:/CSE241/HW1/shellScripts$ bash memory_TestCase_2.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 668.30 MiB/sec
Test 2 of 5
Test 2 completed: 576.41 MiB/sec
Test 3 of 5
Test 3 completed: 619.31 MiB/sec
Test 4 of 5
Test 4 completed: 638.13 MiB/sec
Test 5 of 5
Test 5 completed: 595.17 MiB/sec
Performance Test Results for Throughput:
Average: 597.46 MiB/sec
Minimum: 545.17 MiB/sec
Maximum: 638.13 MiB/sec
Standard Deviation: 32.943284
```

FileIO test case 1

```
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
107740824 bytes written in 11.05 seconds (92.69 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 1.83 Max: 9.03 Avg: 4.84 SD: 2.44
Write Throughput (MiB/s):
Min: 1.89 Max: 6.31 Avg: 3.23 SD: 1.62
azraelkisara@azraelkisara:/CSE241/HW1/shellScripts$
```

FileIO test case 2

```
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
2194880 bytes written in 17.42 seconds (117.89 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 1.83 Max: 11.03 Avg: 7.51 SD: 2.23
Write Throughput (MiB/s):
Min: 3.29 Max: 7.77 Avg: 5.01 SD: 1.48
azraelkisara@azraelkisara:/CSE241/HW1/shellScripts$
```

b) cpu: 2, RAM: 4096

```
azraelkisara@BlueBreaker:~/csen241$ sudo qemu-system-x86_64 -smp 2 -m 4096 -hda ubuntu.img -net user,hostfwd=tcp::10022-:22 -net nic
[sudo] password for azraelkisara:
```

CPU test case 1

```
azraelkisara@azraelkisara:/CSE241/HW1/shellScripts$ bash cpu_TestCase_1.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 254.94 events/sec
Test 2 of 5
Test 2 completed: 256.56 events/sec
Test 3 of 5
Test 3 completed: 235.19 events/sec
Test 4 of 5
Test 4 completed: 235.58 events/sec
Test 5 of 5
Test 5 completed: 235.82 events/sec
Performance Test Results for Events Per Second:
Average: 253.66
Minimum: 235.19
Maximum: 256.56
Standard Deviation: 9.93
azraelkisara@azraelkisara:/CSE241/HW1/shellScripts$
```

CPU test case 2

```
azraelkisara@azraelkisara:/CSE241/HW1/shellScripts$ bash cpu_TestCase_2.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 40.67 events/sec
Test 2 of 5
Test 2 completed: 41.93 events/sec
Test 3 of 5
Test 3 completed: 40.36 events/sec
Test 4 of 5
Test 4 completed: 41.90 events/sec
Test 5 of 5
Test 5 completed: 41.09 events/sec
Performance Test Results for Events Per Second:
Average: 41.19
Minimum: 40.36
Maximum: 41.93
Standard Deviation: .63
azraelkisara@azraelkisara:/CSE241/HW1/shellScripts$
```

Memory test case 1

```
azraelkisara@azraelkisara:/CSE241/HW1/shellScripts$ bash memory_TestCase_1.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 292.53 MiB/sec
Test 2 of 5
Test 2 completed: 300.72 MiB/sec
Test 3 of 5
Test 3 completed: 310.09 MiB/sec
Test 4 of 5
Test 4 completed: 273.46 MiB/sec
Test 5 of 5
Test 5 completed: 220.46 MiB/sec
Performance Test Results for Throughput:
Average: 288.21 MiB/sec
Minimum: 224.06 MiB/sec
Maximum: 310.09 MiB/sec
Standard Deviation: 30.401703
azraelkisara@azraelkisara:/CSE241/HW1/shellScripts$
```

Memory test case 2

```
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ bash memory_testcase_2.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 587.57 MiB/sec
Test 2 of 5
Test 2 completed: 578.93 MiB/sec
Test 3 of 5
Test 3 completed: 596.84 MiB/sec
Test 4 of 5
Test 4 completed: 596.36 MiB/sec
Test 5 of 5
Test 5 completed: 623.20 MiB/sec
Performance Test Results for Throughput:
Average: 596.58 MiB/sec
Minimum: 578.93 MiB/sec
Maximum: 623.20 MiB/sec
Standard Deviation: 14.81967
```

FileIO test case 1

```
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
1073741824 bytes written in 7.93 seconds (129.13 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 6.12 Max: 6.67 Avg: .17
Write Throughput (MiB/s):
Min: 4.88 Max: 4.45 Avg: 4.22 SD: .18
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$
```

FileIO test case 2

```
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ bash memory_testcase_2.sh
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
2147483648 bytes written in 17.45 seconds (117.34 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 6.92 Max: 7.02 Avg: 6.86 SD: .37
Write Throughput (MiB/s):
Min: 3.95 Max: 4.75 Avg: 4.37 SD: .24
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$
```

c) cpu: 4, RAM: 2048

```
azraelkisara@BlueBreaker:~/csen241$ sudo qemu-system-x86_64 -smp 4 -m 2048 -hda ubuntu.img -net user,hostfwd=tcp::10022-22 -net nic
[sudo] password for azraelkisara:
```

CPU test case 1

```
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ bash cpu testcase_1.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 244.78 events/sec
Test 2 of 5
Test 2 completed: 264.97 events/sec
Test 3 of 5
Test 3 completed: 272.85 events/sec
Test 4 of 5
Test 4 completed: 279.35 events/sec
Test 5 of 5
Test 5 completed: 266.84 events/sec
Performance Test Results for Events Per Second:
Average: 265.75
Minimum: 244.78
Maximum: 279.35
Standard Deviation: 11.63
```

CPU test case 2

```
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ bash cpu testcase_2.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 41.07 events/sec
Test 2 of 5
Test 2 completed: 38.14 events/sec
Test 3 of 5
Test 3 completed: 38.94 events/sec
Test 4 of 5
Test 4 completed: 41.07 events/sec
Test 5 of 5
Test 5 completed: 39.34 events/sec
Performance Test Results for Events Per Second:
Average: 39.71
Minimum: 38.14
Maximum: 41.07
Standard Deviation: 1.17
```

Memory test case 1

```
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ bash memory_testcase_1.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 288.00 MiB/sec
Test 2 of 5
Test 2 completed: 305.88 MiB/sec
Test 3 of 5
Test 3 completed: 302.82 MiB/sec
Test 4 of 5
Test 4 completed: 262.69 MiB/sec
Test 5 of 5
Test 5 completed: 201.91 MiB/sec
Performance Test Results for Throughput:
Average: 288.26 MiB/sec
Minimum: 262.69 MiB/sec
Maximum: 305.88 MiB/sec
Standard Deviation: 15.59988
```

Memory test case 2

```
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ bash memory_testcase_2.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 544.14 MiB/sec
Test 2 of 5
Test 2 completed: 600.43 MiB/sec
Test 3 of 5
Test 3 completed: 605.77 MiB/sec
Test 4 of 5
Test 4 completed: 608.71 MiB/sec
Test 5 of 5
Test 5 completed: 610.51 MiB/sec
Performance Test Results for Throughput:
Average: 596.51 MiB/sec
Minimum: 544.14 MiB/sec
Maximum: 610.51 MiB/sec
Standard Deviation: 26.716698
```

FileIO test case 1

```
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
1037418240 bytes written in 8.49 seconds (120.64 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 6.21 Max: 10.57 Avg: 7.18 SD: 1.69
Write Throughput (MiB/s):
Min: 4.14 Max: 7.65 Avg: 4.79 SD: 1.12
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$
```

FileIO test case 2

```
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
2147483648 bytes written in 13.98 seconds (147.34 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 5.16 Max: 6.22 Avg: 5.59 SD: .33
Write Throughput (MiB/s):
Min: 3.44 Max: 4.14 Avg: 3.72 SD: .20
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$
```

d) cpu: 4, RAM: 4096

```
azraelkisara@BlueBreaker:~/csen241$ sudo qemu-system-x86_64 -smp 4 -m 4096 -hda ubuntu.img -net user,hostfwd=tcp::10022-:22 -net nic
[sudo] password for azraelkisara:
```

CPU test case 1

```
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ bash cpu testcase_1.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 259.37 events/sec
Test 2 of 5
Test 2 completed: 265.49 events/sec
Test 3 of 5
Test 3 completed: 250.37 events/sec
Test 4 of 5
Test 4 completed: 268.54 events/sec
Test 5 of 5
Test 5 completed: 266.07 events/sec
Performance Test Results for Events Per Second:
Average: 261.96
Minimum: 250.37
Maximum: 268.54
Standard Deviation: 6.53
```

CPU test case 2

```
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ bash cpu testcase_2.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 40.28 events/sec
Test 2 of 5
Test 2 completed: 42.09 events/sec
Test 3 of 5
Test 3 completed: 41.73 events/sec
Test 4 of 5
Test 4 completed: 39.81 events/sec
Test 5 of 5
Test 5 completed: 41.78 events/sec
Performance Test Results for Events Per Second:
Average: 41.13
Minimum: 39.81
Maximum: 42.09
Standard Deviation: .91
```

Memory test case 1

```
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ bash memory_TestCase_1.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 282.12 MiB/sec
Test 2 of 5
Test 2 completed: 285.78 MiB/sec
Test 3 of 5
Test 3 completed: 256.58 MiB/sec
Test 4 of 5
Test 4 completed: 266.95 MiB/sec
Test 5 of 5
Test 5 completed: 304.58 MiB/sec
Performance Test Results for Throughput:
Average: 279.20 MiB/sec
Minimum: 256.58 MiB/sec
Maximum: 304.58 MiB/sec
Standard Deviation: 16.478288
```

Memory test case 2

```
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ bash memory_TestCase_2.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 489.43 MiB/sec
Test 2 of 5
Test 2 completed: 546.26 MiB/sec
Test 3 of 5
Test 3 completed: 581.06 MiB/sec
Test 4 of 5
Test 4 completed: 580.56 MiB/sec
Test 5 of 5
Test 5 completed: 505.28 MiB/sec
Performance Test Results for Throughput:
Average: 548.51 MiB/sec
Minimum: 489.43 MiB/sec
Maximum: 581.06 MiB/sec
Standard Deviation: 33.444371
```

FileIO test case 1

```
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
097941624 bytes written in 8.64 seconds (118.55 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 9.92 Max: 10.49 Avg: 6.31 SD: 1.09
Write Throughput (MiB/s):
Min: 3.28 Max: 5.46 Avg: 4.20 SD: .72
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ |
```

FileIO test case 2

```
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
0147683648 bytes written in 15.81 seconds (129.54 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 5.37 Max: 7.27 Avg: 6.21 SD: .66
Write Throughput (MiB/s):
Min: 3.58 Max: 4.85 Avg: 4.14 SD: .43
azraelkisara@azraelkisara:~/CSE241/HW1/shellScripts$ |
```

4. Experiment with raw image:

Proof of experiment

a) cpu: 2, RAM: 2048

```
azraelkisara@BlueBreaker:~/csen241$ sudo qemu-system-x86_64 -smp 2 -m 2048 -hda ubuntu-raw.img -net user,hostfwd=tcp::10022:22 -net nic
WARNING: Image format was not specified for 'ubuntu-raw.img' and probing guessed raw.
        Automatically detecting the format is dangerous for raw images, write operations on block 0 will be restricted.
        Specify the 'raw' format explicitly to remove the restrictions.
```

CPU test case 1

```
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$ bash cpu_testcase_1.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 273.38 events/sec
Test 2 of 5
Test 2 completed: 250.27 events/sec
Test 3 of 5
Test 3 completed: 267.49 events/sec
Test 4 of 5
Test 4 completed: 264.51 events/sec
Test 5 of 5
Test 5 completed: 268.87 events/sec
Performance Test Results for Events Per Second:
Average: 264.90
Minimum: 250.27
Maximum: 273.38
Standard Deviation: 7.85
```

CPU test case 2

```
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$ bash cpu_testcase_2.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 40.51 events/sec
Test 2 of 5
Test 2 completed: 39.34 events/sec
Test 3 of 5
Test 3 completed: 39.67 events/sec
Test 4 of 5
Test 4 completed: 41.31 events/sec
Test 5 of 5
Test 5 completed: 42.32 events/sec
Performance Test Results for Events Per Second:
Average: 40.63
Minimum: 39.34
Maximum: 42.32
Standard Deviation: 1.08
```

Memory test case 1

```
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$ bash memory testcase_1.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 264.43 MiB/sec
Test 2 of 5
Test 2 completed: 295.99 MiB/sec
Test 3 of 5
Test 3 completed: 323.53 MiB/sec
Test 4 of 5
Test 4 completed: 313.51 MiB/sec
Test 5 of 5
Test 5 completed: 325.59 MiB/sec
Performance Test Results for Throughput:
Average: 304.61 MiB/sec
Minimum: 264.43 MiB/sec
Maximum: 325.59 MiB/sec
Standard Deviation: 22.654182
```

Memory test case 2

```
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$ bash memory testcase_2.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 517.83 MiB/sec
Test 2 of 5
Test 2 completed: 476.25 MiB/sec
Test 3 of 5
Test 3 completed: 502.62 MiB/sec
Test 4 of 5
Test 4 completed: 513.35 MiB/sec
Test 5 of 5
Test 5 completed: 493.28 MiB/sec
Performance Test Results for Throughput:
Average: 500.66 MiB/sec
Minimum: 476.25 MiB/sec
Maximum: 517.83 MiB/sec
Standard Deviation: 14.899463
```

FileIO test case 1

```

Creating file test_file.107
Creating file test_file.108
Creating file test_file.109
Creating file test_file.110
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
1073741824 bytes written in 8.69 seconds (117.87 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 5.70 Max: 12.55 Avg: 7.86 SD: 2.42
Write Throughput (MiB/s):
Min: 3.80 Max: 8.37 Avg: 5.24 SD: 1.61
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$
```

FileIO test case 2

```

Creating file test_file.107
Creating file test_file.108
Creating file test_file.109
Creating file test_file.110
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
2147483648 bytes written in 14.91 seconds (137.39 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 4.25 Max: 11.90 Avg: 6.23 SD: 2.85
Write Throughput (MiB/s):
Min: 2.83 Max: 7.94 Avg: 4.15 SD: 1.90
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$
```

b) cpu: 2, RAM: 4096

```

azraelkisara@BlueBreaker:~/csen241$ sudo qemu-system-x86_64 -smp 2 -m 4096 -hda ubuntu-raw.img -net user,hostfwd=tcp::10022:122 -net nic
[sudo] password for azraelkisara:
WARNING: Image format was not specified for 'ubuntu-raw.img' and probing guessed raw.
Automatically detecting the format is dangerous for raw images, write operations on block 0 will be restricted.
Specify the 'raw' format explicitly to remove the restrictions.
```

CPU test case 1

```

azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$ bash cpu_testcase_1.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 271.59 events/sec
Test 2 of 5
Test 2 completed: 275.13 events/sec
Test 3 of 5
Test 3 completed: 264.15 events/sec
Test 4 of 5
Test 4 completed: 275.05 events/sec
Test 5 of 5
Test 5 completed: 263.71 events/sec
Performance Test Results for Events Per Second:
Average: 269.92
Minimum: 263.71
Maximum: 275.13
Standard Deviation: 5.06
```

CPU test case 2

```
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$ bash cpu testcase_2.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 40.88 events/sec
Test 2 of 5
Test 2 completed: 41.34 events/sec
Test 3 of 5
Test 3 completed: 42.40 events/sec
Test 4 of 5
Test 4 completed: 43.24 events/sec
Test 5 of 5
Test 5 completed: 42.88 events/sec
Performance Test Results for Events Per Second:
Average: 42.14
Minimum: 40.88
Maximum: 43.24
Standard Deviation: .89
```

Memory test case 1

```
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$ bash memory testcase_1.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 317.01 MiB/sec
Test 2 of 5
Test 2 completed: 298.58 MiB/sec
Test 3 of 5
Test 3 completed: 264.86 MiB/sec
Test 4 of 5
Test 4 completed: 308.41 MiB/sec
Test 5 of 5
Test 5 completed: 304.08 MiB/sec
Performance Test Results for Throughput:
Average: 298.58 MiB/sec
Minimum: 264.86 MiB/sec
Maximum: 317.01 MiB/sec
Standard Deviation: 17.908433
```

Memory test case 2

```
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$ bash memory testcase_2.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 612.79 MiB/sec
Test 2 of 5
Test 2 completed: 636.69 MiB/sec
Test 3 of 5
Test 3 completed: 626.60 MiB/sec
Test 4 of 5
Test 4 completed: 602.10 MiB/sec
Test 5 of 5
Test 5 completed: 627.07 MiB/sec
Performance Test Results for Throughput:
Average: 621.05 MiB/sec
Minimum: 602.10 MiB/sec
Maximum: 636.69 MiB/sec
Standard Deviation: 12.156973
```

FileIO test case 1

```
Creating file test_file.107
Creating file test_file.108
Creating file test_file.109
Creating file test_file.110
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
1073741824 bytes written in 7.09 seconds (144.44 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 6.24 Max: 12.22 Avg: 9.16 SD: 2.53
Write Throughput (MiB/s):
Min: 4.16 Max: 8.15 Avg: 6.10 SD: 1.69
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$
```

FileIO test case 2

```

Creating file test_file.107
Creating file test_file.108
Creating file test_file.109
Creating file test_file.110
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
2147483648 bytes written in 13.81 seconds (148.25 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 5.94 Max: 13.22 Avg: 9.91 SD: 3.18
Write Throughput (MiB/s):
Min: 3.96 Max: 8.82 Avg: 6.60 SD: 2.12
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$
```

c) cpu: 4, RAM: 2048

```

azraelkisara@BlueBreaker:~/csen241$ sudo qemu-system-x86_64 -smp 4 -m 2048 -hda ubuntu-raw.img -net user,hostfwd=tcp::10
022-:22 -net nic
WARNING: Image format was not specified for 'ubuntu-raw.img' and probing guessed raw.
          Automatically detecting the format is dangerous for raw images, write operations on block 0 will be restricted.
          Specify the 'raw' format explicitly to remove the restrictions.
```

CPU test case 1

```

azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$ bash cpu_testcase_1.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 260.22 events/sec
Test 2 of 5
Test 2 completed: 255.30 events/sec
Test 3 of 5
Test 3 completed: 256.23 events/sec
Test 4 of 5
Test 4 completed: 261.81 events/sec
Test 5 of 5
Test 5 completed: 266.57 events/sec
Performance Test Results for Events Per Second:
Average: 260.02
Minimum: 255.30
Maximum: 266.57
Standard Deviation: 4.06
```

CPU test case 2

```

azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$ bash cpu_testcase_2.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 40.48 events/sec
Test 2 of 5
Test 2 completed: 39.18 events/sec
Test 3 of 5
Test 3 completed: 42.46 events/sec
Test 4 of 5
Test 4 completed: 41.86 events/sec
Test 5 of 5
Test 5 completed: 42.81 events/sec
Performance Test Results for Events Per Second:
Average: 41.35
Minimum: 39.18
Maximum: 42.81
Standard Deviation: 1.34
```

Memory test case 1

```
Standard Deviation: 1.54
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$ bash memory_testcase_1.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 326.31 MiB/sec
Test 2 of 5
Test 2 completed: 313.99 MiB/sec
Test 3 of 5
Test 3 completed: 312.83 MiB/sec
Test 4 of 5
Test 4 completed: 294.55 MiB/sec
Test 5 of 5
Test 5 completed: 309.62 MiB/sec
Performance Test Results for Throughput:
Average: 311.46 MiB/sec
Minimum: 294.55 MiB/sec
Maximum: 326.31 MiB/sec
Standard Deviation: 10.179489
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$
```

Memory test case 2

```
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$ bash memory_testcase_2.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 608.58 MiB/sec
Test 2 of 5
Test 2 completed: 611.46 MiB/sec
Test 3 of 5
Test 3 completed: 603.09 MiB/sec
Test 4 of 5
Test 4 completed: 512.68 MiB/sec
Test 5 of 5
Test 5 completed: 534.90 MiB/sec
Performance Test Results for Throughput:
Average: 574.14 MiB/sec
Minimum: 512.68 MiB/sec
Maximum: 611.46 MiB/sec
Standard Deviation: 41.794951
```

FileIO test case 1

```
Creating file test_file.107
Creating file test_file.108
Creating file test_file.109
Creating file test_file.110
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
1073741824 bytes written in 6.98 seconds (146.78 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 5.81 Max: 13.87 Avg: 9.47 SD: 3.47
Write Throughput (MiB/s):
Min: 3.88 Max: 9.25 Avg: 6.31 SD: 2.31
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$
```

FileIO test case 2

```

Creating file test_file.107
Creating file test_file.108
Creating file test_file.109
Creating file test_file.110
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
2147483648 bytes written in 14.00 seconds (146.27 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 5.07 Max: 11.30 Avg: 7.98 SD: 2.55
Write Throughput (MiB/s):
Min: 3.38 Max: 7.54 Avg: 5.32 SD: 1.70
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$
```

d) cpu: 4, RAM: 4096

```

azraelkisara@BlueBreaker:~/cse241$ sudo qemu-system-x86_64 -smp 4 -m 4096 -hda ubuntu-raw.img -net user,hostfwd=tcp::10
022:22 -net nic
[sudo] password for azraelkisara:
WARNING: Image format was not specified for 'ubuntu-raw.img' and probing guessed raw.
        Automatically detecting the format is dangerous for raw images, write operations on block 0 will be restricted.
        Specify the 'raw' format explicitly to remove the restrictions.
```

CPU test case 1

```

azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$ bash cpu_testcase_1.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 271.37 events/sec
Test 2 of 5
Test 2 completed: 275.64 events/sec
Test 3 of 5
Test 3 completed: 265.22 events/sec
Test 4 of 5
Test 4 completed: 280.61 events/sec
Test 5 of 5
Test 5 completed: 281.30 events/sec
Performance Test Results for Events Per Second:
Average: 274.82
Minimum: 265.22
Maximum: 281.30
Standard Deviation: 6.00
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$
```

CPU test case 2

```

azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$ bash cpu_testcase_2.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 38.97 events/sec
Test 2 of 5
Test 2 completed: 40.60 events/sec
Test 3 of 5
Test 3 completed: 43.05 events/sec
Test 4 of 5
Test 4 completed: 40.54 events/sec
Test 5 of 5
Test 5 completed: 42.19 events/sec
Performance Test Results for Events Per Second:
Average: 41.07
Minimum: 38.97
Maximum: 43.05
Standard Deviation: 1.41
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$
```

Memory test case 1

```
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$ bash memory_testcase_1.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 331.37 MiB/sec
Test 2 of 5
Test 2 completed: 318.62 MiB/sec
Test 3 of 5
Test 3 completed: 279.61 MiB/sec
Test 4 of 5
Test 4 completed: 303.36 MiB/sec
Test 5 of 5
Test 5 completed: 319.45 MiB/sec
Performance Test Results for Throughput:
Average: 310.48 MiB/sec
Minimum: 279.61 MiB/sec
Maximum: 331.37 MiB/sec
Standard Deviation: 17.814263
```

Memory test case 2

```
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$ bash memory_testcase_2.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 576.71 MiB/sec
Test 2 of 5
Test 2 completed: 491.18 MiB/sec
Test 3 of 5
Test 3 completed: 536.74 MiB/sec
Test 4 of 5
Test 4 completed: 581.71 MiB/sec
Test 5 of 5
Test 5 completed: 559.13 MiB/sec
Performance Test Results for Throughput:
Average: 549.09 MiB/sec
Minimum: 491.18 MiB/sec
Maximum: 581.71 MiB/sec
Standard Deviation: 32.966043
```

FileIO test case 1

```
Creating file test_file.107
Creating file test_file.108
Creating file test_file.109
Creating file test_file.110
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
1073741824 bytes written in 7.42 seconds (138.02 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 6.23 Max: 12.07 Avg: 8.38 SD: 2.37
Write Throughput (MiB/s):
Min: 4.16 Max: 8.05 Avg: 5.59 SD: 1.58
```

```
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$
```

FileIO test case 2

```

Creating file test_file.107
Creating file test_file.108
Creating file test_file.109
Creating file test_file.110
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
2147483648 bytes written in 14.13 seconds (144.96 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 6.41 Max: 14.82 Avg: 9.78 SD: 3.12
Write Throughput (MiB/s):
Min: 4.27 Max: 9.88 Avg: 6.52 SD: 2.08
azraelkisara@azraelkisararaw:~/CSE241/HW1/shellScripts$
```

Docker Experiment

1. Start Container

Run the following command to start container from image

```
sudo docker run --cpus <cpu percentage> --memory <memory limit>m -it <image> /bin/bash
```

My host has 24 cpus, to limit to 2 cpus, cpus = “0.09”. to limit to 4 cpus cpus = “0.17”

2. Experiment with docker image:

Proof of experiment

a) cpu: 2, RAM: 2048

```
azraelkisara@BlueBreaker:~/csen241$ sudo docker run -t --cpus="0.09" --memory=2048m -it docker-ubuntu /bin/bash
[sudo] password for azraelkisara:
```

CPU test case 1

```
root@167f2b8c5671:/home/CSE241/HW1/shellScripts# bash cpu testcase_1.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 173.25 events/sec
Test 2 of 5
Test 2 completed: 173.69 events/sec
Test 3 of 5
Test 3 completed: 160.89 events/sec
Test 4 of 5
Test 4 completed: 167.47 events/sec
Test 5 of 5
Test 5 completed: 173.89 events/sec
Performance Test Results for Events Per Second:
Average: 169.83
Minimum: 160.89
Maximum: 173.89
Standard Deviation: 5.06
root@167f2b8c5671:/home/CSE241/HW1/shellScripts#
```

CPU test case 2

```
Standard Deviation: .00
root@167f2b8c5671:/home/CSE241/HW1/shellScripts# bash cpu testcase_2.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 26.10 events/sec
Test 2 of 5
Test 2 completed: 27.00 events/sec
Test 3 of 5
Test 3 completed: 27.39 events/sec
Test 4 of 5
Test 4 completed: 27.35 events/sec
Test 5 of 5
Test 5 completed: 26.80 events/sec
Performance Test Results for Events Per Second:
Average: 26.92
Minimum: 26.10
Maximum: 27.39
Standard Deviation: .45
```

Memory test case 1

```
root@167f2b8c5671:/home/CSE241/HW1/shellScripts# bash memory testcase_1.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 698.77 MiB/sec
Test 2 of 5
Test 2 completed: 705.52 MiB/sec
Test 3 of 5
Test 3 completed: 698.71 MiB/sec
Test 4 of 5
Test 4 completed: 673.52 MiB/sec
Test 5 of 5
Test 5 completed: 680.73 MiB/sec
Performance Test Results for Throughput:
Average: 691.45 MiB/sec
Minimum: 673.52 MiB/sec
Maximum: 705.52 MiB/sec
Standard Deviation: 12.170702
```

Memory test case 2

```
root@167f2b8c5671:/home/CSE241/HW1/shellScripts# bash memory testcase_2.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 1108.23 MiB/sec
Test 2 of 5
Test 2 completed: 1080.89 MiB/sec
Test 3 of 5
Test 3 completed: 1086.69 MiB/sec
Test 4 of 5
Test 4 completed: 1079.60 MiB/sec
Test 5 of 5
Test 5 completed: 1089.75 MiB/sec
Performance Test Results for Throughput:
Average: 1089.03 MiB/sec
Minimum: 1079.60 MiB/sec
Maximum: 1108.23 MiB/sec
Standard Deviation: 10.293590
```

FileIO test case 1

```
Creating file test_file.107
Creating file test_file.108
Creating file test_file.109
Creating file test_file.110
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
1073741824 bytes written in 6.70 seconds (152.74 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 28.54 Max: 38.27 Avg: 33.72 SD: 3.82
Write Throughput (MiB/s):
Min: 19.03 Max: 25.52 Avg: 22.48 SD: 2.55
root@167f2b8c5671:/home/CSE241/HW1/shellScripts#
```

FileIO test case 2

```

Creating file test_file.107
Creating file test_file.108
Creating file test_file.109
Creating file test_file.110
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
2147483648 bytes written in 12.91 seconds (158.64 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 26.76 Max: 38.09 Avg: 34.12 SD: 4.02
Write Throughput (MiB/s):
Min: 17.84 Max: 25.40 Avg: 22.74 SD: 2.68
root@167f2b8c5671:/home/CSE241/HW1/shellScripts#

```

b) cpu: 2, RAM: 4096

```

azraelkisara@BlueBreaker:~/csen241$ sudo docker run -t --cpus="0.09" --memory=4096m -it docker-ubuntu /bin/bash
[sudo] password for azraelkisara:

```

CPU test case 1

```

root@b439b01b2458:/CSE241/HW1/shellScripts# bash cpu_testcase_1.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 177.48 events/sec
Test 2 of 5
Test 2 completed: 176.44 events/sec
Test 3 of 5
Test 3 completed: 179.34 events/sec
Test 4 of 5
Test 4 completed: 178.19 events/sec
Test 5 of 5
Test 5 completed: 178.29 events/sec
Performance Test Results for Events Per Second:
Average: 177.94
Minimum: 176.44
Maximum: 179.34
Standard Deviation: .95
root@b439b01b2458:/CSE241/HW1/shellScripts#

```

CPU test case 2

```

root@b439b01b2458:/CSE241/HW1/shellScripts# bash cpu_testcase_2.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 27.27 events/sec
Test 2 of 5
Test 2 completed: 26.79 events/sec
Test 3 of 5
Test 3 completed: 27.15 events/sec
Test 4 of 5
Test 4 completed: 27.11 events/sec
Test 5 of 5
Test 5 completed: 27.15 events/sec
Performance Test Results for Events Per Second:
Average: 27.09
Minimum: 26.79
Maximum: 27.27
Standard Deviation: .14
root@b439b01b2458:/CSE241/HW1/shellScripts#

```

Memory test case 1

```

root@b439b01b2458:/CSE241/HW1/shellScripts# bash memory testcase_1.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 677.46 MiB/sec
Test 2 of 5
Test 2 completed: 686.16 MiB/sec
Test 3 of 5
Test 3 completed: 684.09 MiB/sec
Test 4 of 5
Test 4 completed: 690.20 MiB/sec
Test 5 of 5
Test 5 completed: 691.94 MiB/sec
Performance Test Results for Throughput:
Average: 685.97 MiB/sec
Minimum: 677.46 MiB/sec
Maximum: 691.94 MiB/sec
Standard Deviation: 5.089400
root@b439b01b2458:/CSE241/HW1/shellScripts#

```

Memory test case 2

```
root@b439b01b2458:/CSE241/HW1/shellScripts# bash memory_testcase_2.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 1090.06 MiB/sec
Test 2 of 5
Test 2 completed: 1125.34 MiB/sec
Test 3 of 5
Test 3 completed: 1104.64 MiB/sec
Test 4 of 5
Test 4 completed: 1114.72 MiB/sec
Test 5 of 5
Test 5 completed: 1124.13 MiB/sec
Performance Test Results for Throughput:
Average: 1111.77 MiB/sec
Minimum: 1090.06 MiB/sec
Maximum: 1125.34 MiB/sec
Standard Deviation: 13.173837
```

FileIO test case 1

```
Creating file test_file.107
Creating file test_file.108
Creating file test_file.109
Creating file test_file.110
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
1073741824 bytes written in 6.71 seconds (152.69 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 34.25 Max: 41.93 Avg: 37.66 SD: 3.01
Write Throughput (MiB/s):
Min: 22.83 Max: 27.96 Avg: 25.10 SD: 2.00
root@b439b01b2458:/CSE241/HW1/shellScripts#
```

FileIO test case 2

```
Creating file test_file.107
Creating file test_file.108
Creating file test_file.109
Creating file test_file.110
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
2147483648 bytes written in 12.70 seconds (161.23 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 29.81 Max: 40.44 Avg: 35.62 SD: 3.46
Write Throughput (MiB/s):
Min: 19.87 Max: 26.96 Avg: 23.74 SD: 2.31
root@b439b01b2458:/CSE241/HW1/shellScripts#
```

c) cpu: 4, RAM: 2048

```
azraelkisara@BlueBreaker:~/csen241$ sudo docker run -it --cpus="0.17" --memory=2048m -it docker-ubuntu /bin/bash
[sudo] password for azraelkisara:
root@ea6fc736e2f3:/#
```

CPU test case 1

```
root@ea6fc736e2f3:/CSE241/HW1/shellScripts# bash cpu_testcase_1.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 330.09 events/sec
Test 2 of 5
Test 2 completed: 329.63 events/sec
Test 3 of 5
Test 3 completed: 337.59 events/sec
Test 4 of 5
Test 4 completed: 323.22 events/sec
Test 5 of 5
Test 5 completed: 332.13 events/sec
Performance Test Results for Events Per Second:
Average: 330.53
Minimum: 323.22
Maximum: 337.59
Standard Deviation: 4.62
```

CPU test case 2

```
root@ea6fc736e2f3:/CSE241/HW1/shellScripts# bash cpu_testcase_2.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 51.48 events/sec
Test 2 of 5
Test 2 completed: 50.85 events/sec
Test 3 of 5
Test 3 completed: 51.49 events/sec
Test 4 of 5
Test 4 completed: 51.25 events/sec
Test 5 of 5
Test 5 completed: 51.64 events/sec
Performance Test Results for Events Per Second:
Average: 51.34
Minimum: 50.85
Maximum: 51.64
Standard Deviation: .26
```

Memory test case 1

```
root@ea6fc736e2f3:/CSE241/HW1/shellScripts# bash memory_testcase_1.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 1284.67 MiB/sec
Test 2 of 5
Test 2 completed: 1295.72 MiB/sec
Test 3 of 5
Test 3 completed: 1311.72 MiB/sec
Test 4 of 5
Test 4 completed: 1293.28 MiB/sec
Test 5 of 5
Test 5 completed: 1278.02 MiB/sec
Performance Test Results for Throughput:
Average: 1292.68 MiB/sec
Minimum: 1278.02 MiB/sec
Maximum: 1311.72 MiB/sec
Standard Deviation: 11.412186
root@ea6fc736e2f3:/CSE241/HW1/shellScripts#
```

Memory test case 2

```
root@ea6fc736e2f3:/CSE241/HW1/shellScripts# bash memory_testcase_2.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 2031.13 MiB/sec
Test 2 of 5
Test 2 completed: 2063.85 MiB/sec
Test 3 of 5
Test 3 completed: 2091.37 MiB/sec
Test 4 of 5
Test 4 completed: 2124.34 MiB/sec
Test 5 of 5
Test 5 completed: 2094.78 MiB/sec
Performance Test Results for Throughput:
Average: 2081.09 MiB/sec
Minimum: 2031.13 MiB/sec
Maximum: 2124.34 MiB/sec
Standard Deviation: 31.486028
```

FileIO test case 1

```

Creating file test_file.107
Creating file test_file.108
Creating file test_file.109
Creating file test_file.110
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
1073741824 bytes written in 3.40 seconds (301.17 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 35.33 Max: 46.52 Avg: 40.16 SD: 3.98
Write Throughput (MiB/s):
Min: 23.56 Max: 31.01 Avg: 26.77 SD: 2.65
root@ea6fc736e2f3:/CSE241/HW1/shellScripts#

```

FileIO test case 2

```

Creating file test_file.107
Creating file test_file.108
Creating file test_file.109
Creating file test_file.110
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
2147483648 bytes written in 6.99 seconds (292.84 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 34.92 Max: 41.37 Avg: 38.31 SD: 2.24
Write Throughput (MiB/s):
Min: 23.28 Max: 27.58 Avg: 25.54 SD: 1.50
root@ea6fc736e2f3:/CSE241/HW1/shellScripts#

```

d) cpu: 4, RAM: 4096

```

azraelkisara@BlueBreaker:~/cse241$ sudo docker run -it --cpus="0.17" --memory=4096m -it docker-ubuntu /bin/bash
[sudo] password for azraelkisara:
root@674ec73b702d:#

```

CPU test case 1

```

root@674ec73b702d:/CSE241/HW1/shellScripts# bash cpu_testcase_1.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 333.33 events/sec
Test 2 of 5
Test 2 completed: 335.99 events/sec
Test 3 of 5
Test 3 completed: 338.28 events/sec
Test 4 of 5
Test 4 completed: 334.13 events/sec
Test 5 of 5
Test 5 completed: 330.19 events/sec
Performance Test Results for Events Per Second:
Average: 334.38
Minimum: 330.19
Maximum: 338.28
Standard Deviation: 2.70
root@674ec73b702d:/CSE241/HW1/shellScripts#

```

CPU test case 2

```
root@674ec73b702d:/CSE241/HW1/shellScripts# bash cpu testcase_2.sh
Running Sysbench CPU tests...
Test 1 of 5
Test 1 completed: 48.78 events/sec
Test 2 of 5
Test 2 completed: 51.31 events/sec
Test 3 of 5
Test 3 completed: 50.54 events/sec
Test 4 of 5
Test 4 completed: 51.80 events/sec
Test 5 of 5
Test 5 completed: 50.79 events/sec
Performance Test Results for Events Per Second:
Average: 50.64
Minimum: 48.78
Maximum: 51.80
Standard Deviation: 1.02
```

Memory test case 1

```
root@674ec73b702d:/CSE241/HW1/shellScripts# bash memory testcase_1.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 1259.40 MiB/sec
Test 2 of 5
Test 2 completed: 1292.27 MiB/sec
Test 3 of 5
Test 3 completed: 1292.96 MiB/sec
Test 4 of 5
Test 4 completed: 1256.07 MiB/sec
Test 5 of 5
Test 5 completed: 1264.90 MiB/sec
Performance Test Results for Throughput:
Average: 1273.12 MiB/sec
Minimum: 1256.07 MiB/sec
Maximum: 1292.96 MiB/sec
Standard Deviation: 16.166817
```

Memory test case 2

```
root@674ec73b702d:/CSE241/HW1/shellScripts# bash memory testcase_2.sh
Running Sysbench Memory tests...
Test 1 of 5
Test 1 completed: 1856.05 MiB/sec
Test 2 of 5
Test 2 completed: 1981.19 MiB/sec
Test 3 of 5
Test 3 completed: 2074.45 MiB/sec
Test 4 of 5
Test 4 completed: 2053.46 MiB/sec
Test 5 of 5
Test 5 completed: 2022.51 MiB/sec
Performance Test Results for Throughput:
Average: 1997.53 MiB/sec
Minimum: 1856.05 MiB/sec
Maximum: 2074.45 MiB/sec
Standard Deviation: 77.398217
root@674ec73b702d:/CSE241/HW1/shellScripts#
```

FileIO test case 1

```
Creating file test_file.107
Creating file test_file.108
Creating file test_file.109
Creating file test_file.110
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
1073741824 bytes written in 4.10 seconds (249.78 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 12.21 Max: 16.00 Avg: 14.09 SD: 1.57
Write Throughput (MiB/s):
Min: 8.14 Max: 10.67 Avg: 9.40 SD: 1.04
root@674ec73b702d:/CSE241/HW1/shellScripts#
```

FileIO test case 2

```

Creating file test_file.107
Creating file test_file.108
Creating file test_file.109
Creating file test_file.110
Creating file test_file.111
Creating file test_file.112
Creating file test_file.113
Creating file test_file.114
Creating file test_file.115
Creating file test_file.116
Creating file test_file.117
Creating file test_file.118
Creating file test_file.119
Creating file test_file.120
Creating file test_file.121
Creating file test_file.122
Creating file test_file.123
Creating file test_file.124
Creating file test_file.125
Creating file test_file.126
Creating file test_file.127
2147483648 bytes written in 7.19 seconds (284.83 MiB/sec).
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Removing test files...
Read Throughput (MiB/s):
Min: 11.73 Max: 24.52 Avg: 16.63 SD: 5.48
Write Throughput (MiB/s):
Min: 7.82 Max: 16.34 Avg: 11.08 SD: 3.65
root@674ec73b702d:/CSE241/HW1/shellScripts#

```

Measurements

CPU Test (events/sec)

Image	CPU	RAM	Parameter	Value	min	max	avg	sd
qcow2	2	2048	cpu-max-prime	20000	236.52	266.75	252.27	9.59
qcow2	2	2048	cpu-max-prime	80000	38.49	40.56	39.66	0.68
qcow2	2	4096	cpu-max-prime	20000	235.19	256.56	243.60	9.93
qcow2	2	4096	cpu-max-prime	80000	40.36	41.93	41.19	0.63
qcow2	4	2048	cpu-max-prime	20000	244.78	279.35	265.75	11.63
qcow2	4	2048	cpu-max-prime	80000	38.14	41.07	39.71	1.17
qcow2	4	4096	cpu-max-prime	20000	250.37	268.54	261.96	6.53
qcow2	4	4096	cpu-max-prime	80000	39.81	42.09	41.13	0.91
raw	2	2048	cpu-max-prime	20000	250.27	273.38	264.90	7.85
raw	2	2048	cpu-max-prime	80000	39.34	42.32	40.63	1.08
raw	2	4096	cpu-max-prime	20000	263.71	275.13	269.92	5.06
raw	2	4096	cpu-max-prime	80000	40.88	43.24	42.14	0.89
raw	4	2048	cpu-max-prime	20000	255.30	266.57	260.02	4.06
raw	4	2048	cpu-max-prime	80000	39.18	42.81	41.35	1.34
raw	4	4096	cpu-max-prime	20000	265.22	281.30	274.82	6.00
raw	4	4096	cpu-max-prime	80000	38.97	43.05	41.07	1.41
docker	2	2048	cpu-max-prime	20000	160.89	173.89	169.83	5.06
docker	2	2048	cpu-max-prime	80000	26.10	27.39	26.92	0.45
docker	2	4096	cpu-max-prime	20000	176.44	179.34	177.94	0.95
docker	2	4096	cpu-max-prime	80000	26.79	27.27	27.09	0.14
docker	4	2048	cpu-max-prime	20000	323.22	337.59	330.53	4.62
docker	4	2048	cpu-max-prime	80000	50.85	51.64	51.34	0.26
docker	4	4096	cpu-max-prime	20000	330.19	338.28	334.38	2.70
docker	4	4096	cpu-max-prime	80000	48.78	51.80	50.64	1.02

Memory Test (MiB/sec)

Image	CPU	RAM	Parameter	Value	min	max	avg	sd
qcow2	2	2048	memory_block_size	1K	287.49	331.24	318.46	16
qcow2	2	2048	memory_block_size	2K	545.17	638.13	597.46	32.94
qcow2	2	4096	memory_block_size	1K	224.46	310.09	280.21	30.40
qcow2	2	4096	memory_block_size	2K	578.93	623.20	596.58	14.84
qcow2	4	2048	memory_block_size	1K	262.69	305.88	288.26	15.59
qcow2	4	2048	memory_block_size	2K	544.14	619.51	596.51	26.71
qcow2	4	4096	memory_block_size	1K	256.58	304.58	279.20	16.47
qcow2	4	4096	memory_block_size	2K	489.43	581.06	548.51	33.44
raw	2	2048	memory_block_size	1K	264.43	325.59	304.61	22.65
raw	2	2048	memory_block_size	2K	476.25	517.83	500.66	14.89
raw	2	4096	memory_block_size	1K	264.86	317.01	298.58	17.90
raw	2	4096	memory_block_size	2K	602.10	636.69	621.05	12.15
raw	4	2048	memory_block_size	1K	294.55	326.31	311.46	10.17
raw	4	2048	memory_block_size	2K	512.68	611.46	574.17	41.79
raw	4	4096	memory_block_size	1K	279.61	331.37	310.48	17.81
raw	4	4096	memory_block_size	2K	491.18	581.71	549.09	32.96
docker	2	2048	memory_block_size	1K	673.52	705.52	691.45	12.17
docker	2	2048	memory_block_size	2K	1079.60	1108.23	1089.03	10.29
docker	2	4096	memory_block_size	1K	677.46	691.94	685.97	5.08
docker	2	4096	memory_block_size	2K	1090.06	1125.34	1111.77	13.17
docker	4	2048	memory_block_size	1K	1278.02	1311.72	1292.68	11.41

docker	4	2048	memory_block_size	2K	2031.13	2124.34	2081.09	31.48
docker	4	4096	memory_block_size	1K	1256.07	1296.96	1273.12	16.17
docker	4	4096	memory_block_size	2K	1856.05	2074.45	1997.53	77.39

File I/O Test (MiB/Sec) - Random Read

Image	CPU	RAM	Parameter	Value	min	max	avg	sd
qcow2	2	2048	file-total size	1G	2.83	9.47	4.84	2.44
qcow2	2	2048	file-total size	2G	4.93	11.65	7.51	2.23
qcow2	2	4096	file-total size	1G	6.12	6.67	6.33	0.17
qcow2	2	4096	file-total size	2G	5.92	7.12	6.56	0.37
qcow2	4	2048	file-total size	1G	6.21	10.57	7.18	1.69
qcow2	4	2048	file-total size	2G	5.16	6.22	5.59	0.33
qcow2	4	4096	file-total size	1G	4.92	8.19	6.31	1.09
qcow2	4	4096	file-total size	2G	5.37	7.27	6.21	0.66
raw	2	2048	file-total size	1G	5.70	12.55	7.86	2.42
raw	2	2048	file-total size	2G	4.25	11.90	6.23	2.85
raw	2	4096	file-total size	1G	6.24	12.22	9.16	2.53
raw	2	4096	file-total size	2G	5.94	13.22	9.91	3.18
raw	4	2048	file-total size	1G	5.81	13.87	9.47	3.47
raw	4	2048	file-total size	2G	5.07	11.30	7.98	2.55
raw	4	4096	file-total size	1G	6.23	12.07	8.38	2.37
raw	4	4096	file-total size	2G	6.41	14.82	9.78	3.12
docker	2	2048	file-total size	1G	28.54	38.27	33.72	3.82
docker	2	2048	file-total size	2G	26.76	38.09	34.12	4.02
docker	2	4096	file-total size	1G	34.25	41.93	37.66	3.01

docker	2	4096	file-total size	2G	29.81	40.44	35.62	3.46
docker	4	2048	file-total size	1G	35.33	46.52	40.16	3.98
docker	4	2048	file-total size	2G	34.92	41.37	38.31	2.24
docker	4	4096	file-total size	1G	12.21	16.00	14.09	1.57
docker	4	4096	file-total size	2G	11.73	24.52	16.63	5.48

File I/O Test (MiB/Sec) - Random Write

Image	CPU	RAM	Parameter	Value	min	max	avg	sd
qcow2	2	2048	file-total size	1G	1.89	6.31	3.23	1.62
qcow2	2	2048	file-total size	2G	3.29	7.77	5.01	1.48
qcow2	2	4096	file-total size	1G	4.08	4.45	4.22	0.1
qcow2	2	4096	file-total size	2G	3.95	4.75	4.37	0.24
qcow2	4	2048	file-total size	1G	4.14	7.05	4.79	1.12
qcow2	4	2048	file-total size	2G	3.44	4.14	3.72	0.20
qcow2	4	4096	file-total size	1G	3.28	5.46	4.20	0.72
qcow2	4	4096	file-total size	2G	3.58	4.85	4.14	0.43
raw	2	2048	file-total size	1G	3.80	8.37	5.24	1.61
raw	2	2048	file-total size	2G	2.83	7.94	4.15	1.90
raw	2	4096	file-total size	1G	4.16	8.15	6.10	1.69
raw	2	4096	file-total size	2G	3.96	8.82	6.60	2.12
raw	4	2048	file-total size	1G	3.88	9.25	6.31	2.31
raw	4	2048	file-total size	2G	3.38	7.54	5.32	1.70
raw	4	4096	file-total size	1G	4.16	8.05	5.59	1.58
raw	4	4096	file-total size	2G	4.27	9.88	6.52	2.08
docker	2	2048	file-total size	1G	19.03	25.52	22.48	2.55
docker	2	2048	file-total	2G	17.84	25.40	22.74	2.68

			size					
docker	2	4096	file-total size	1G	22.83	27.96	25.10	2.00
docker	2	4096	file-total size	2G	19.87	26.96	23.74	2.31
docker	4	2048	file-total size	1G	23.56	31.01	26.77	2.65
docker	4	2048	file-total size	2G	23.28	27.58	25.54	1.50
docker	4	4096	file-total size	1G	8.14	10.67	9.40	1.04
docker	4	4096	file-total size	2G	7.82	16.34	11.08	3.65

Performance Analysis

CPU test

The metric I use to assess CPU performance is throughput (events/s). The two test cases I run are cpu-max-prime 20000 and cpu-max-prime 80000. Essentially, the test translates to: looping over numbers and checking if they are divisible only by themselves. The higher the number, the lower the throughput.

For qemu images, I expect the performance of the raw image to be better than that of the qcow2 image due to the additional overhead associated with qcow2, which is consistent with the data I observed. We do see that the performance of the raw image is slightly better than that of qcow2. The change in RAM doesn't significantly impact performance, which is expected. Interestingly, for qemu images, changes in CPU also don't affect performance much, whereas for Docker, we observe that performance nearly doubles if the CPU is doubled.

My analysis of this observation is that I set the CPU as a percentage for Docker, so Docker limits the hardware based on this percentage, while qemu limits the hardware based on CPU numbers. For a powerful, modern CPU, the sysbench CPU test workload is not heavy enough to create a noticeable difference between different CPU numbers. To discern a difference, I should modify the thread numbers.

Memory test

The metric I use to assess memory performance is throughput (MiB/sec). The two test cases I run are with memory-block-sizes of 1KB and 2KB. The benchmark application allocates a memory buffer and then reads or writes from it, each time for the size of a pointer, and each execution is for the total size of the memory volume. The default operation is writing.

We notice that for all images, doubling the memory-block-size nearly doubles the memory write speed, which is in line with our expectations. Changes in the hardware CPU and RAM storage should not affect the memory write performance, since the

memory buffer test size is much smaller than the RAM storage limit. However, we do expect different images to exhibit varying memory speeds due to overheads. I anticipate Docker to be the fastest, followed by raw, and then qcow2 being the slowest. From my data, I observe that Docker performs the best, as expected, while the performances of raw and qcow2 are quite close. The memory test shows a large standard deviation; the overhead difference between raw and qcow2 doesn't seem significant.

File I/O test

The metric I use to assess file I/O performance is throughput (MiB/sec). The two test cases I run involve file-total-sizes of 1GB and 2GB, with operations comprising a combination of random reads and writes. The tests are conducted at a ratio of 80% reads to 20% writes.

From my observations, changes in the hardware CPU and RAM do not significantly affect the I/O performance, similar to the file total size. However, we do observe a performance difference between different images. As expected, the Docker image exhibits the best I/O performance, followed by the raw image, and then the qcow2 image.