CSEN 241 HW1

System vs OS Virtualization

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**Computer Architecture:**

This experiment ran on a computer with architecture: x86\_64

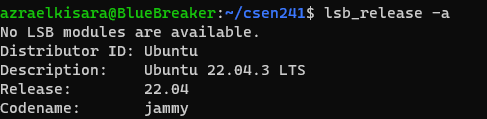
**Operating System:**

This experiment ran on Windows 11 with [WSL2](https://learn.microsoft.com/en-us/windows/wsl/install)

The Windows Subsytem 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



**Git Repo:**

**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**

1. Download Ubuntu 20.04 Server

**wget <https://releases.ubuntu.com/focal/ubuntu-20.04.6-live-server-amd64.iso>**

1. 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**

1. 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**

1. Created Images



**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)

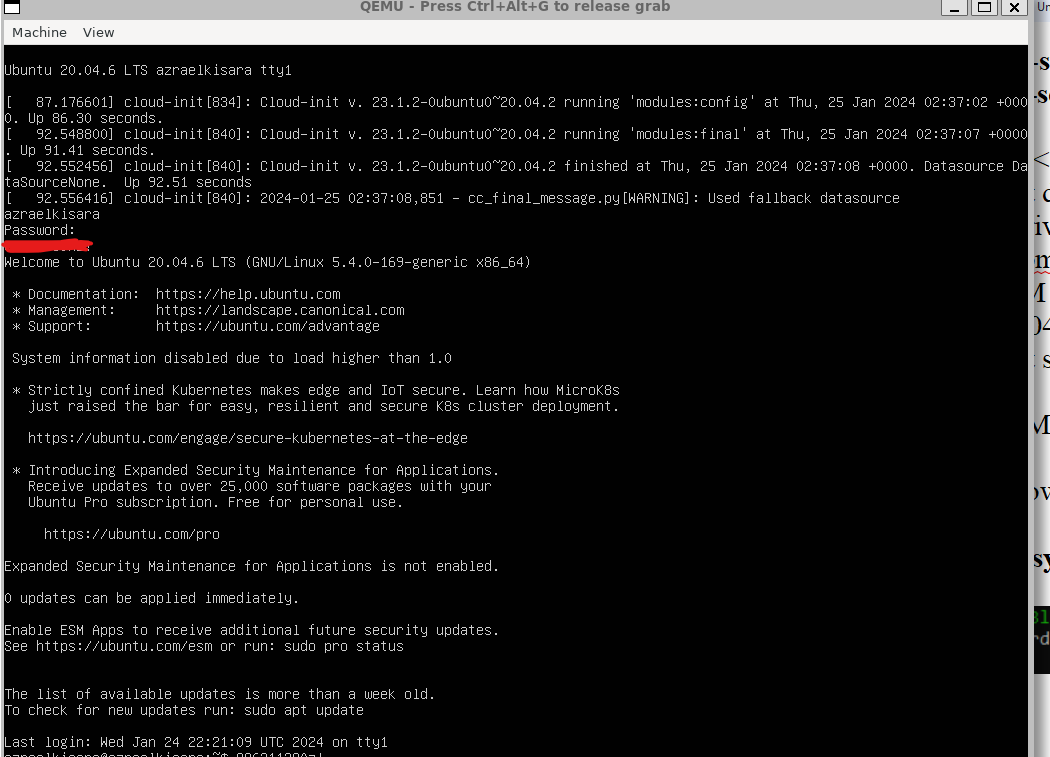
-boot strict=on: enables strict boot order

1. 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`>**





**Create Docker container Image**

1. Install Docker

Follow [instruction](https://docs.docker.com/engine/install/ubuntu/) to install Docker engine on Ubuntu.

1. Create a Dockerfile

**touch Dockerfile**

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

**FROM ubuntu:20.04**

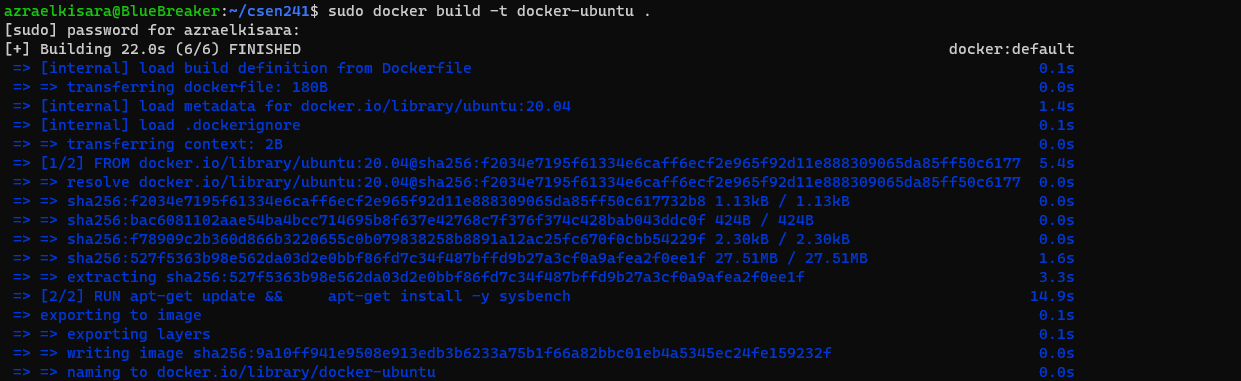
**Run apt-get update && apt-get install -y sysbench**

1. Build the image from edited Dockerfile

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

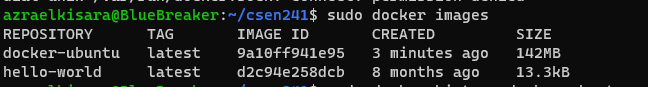
image name.

**sudo docker build -t <tag> .**



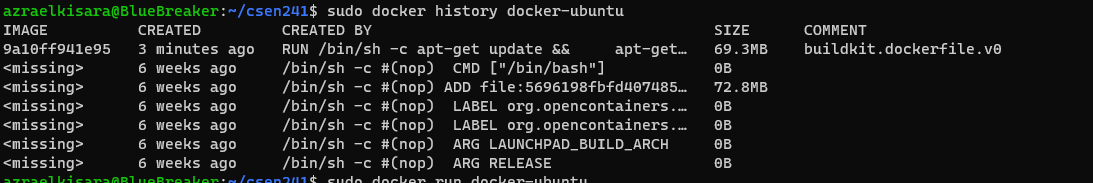
1. Check image ID

**sudo docker images**



1. Check image history

**sudo docker history <tag>**



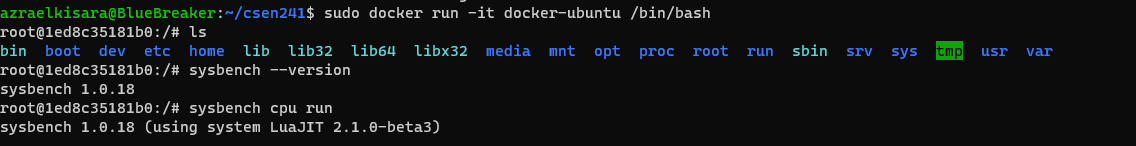
1. Run the container

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



1. Other useful docker commands

**docker ps**

This command list all running containers



**docker stop <NAMES>**

This command stop the container with given name



**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**

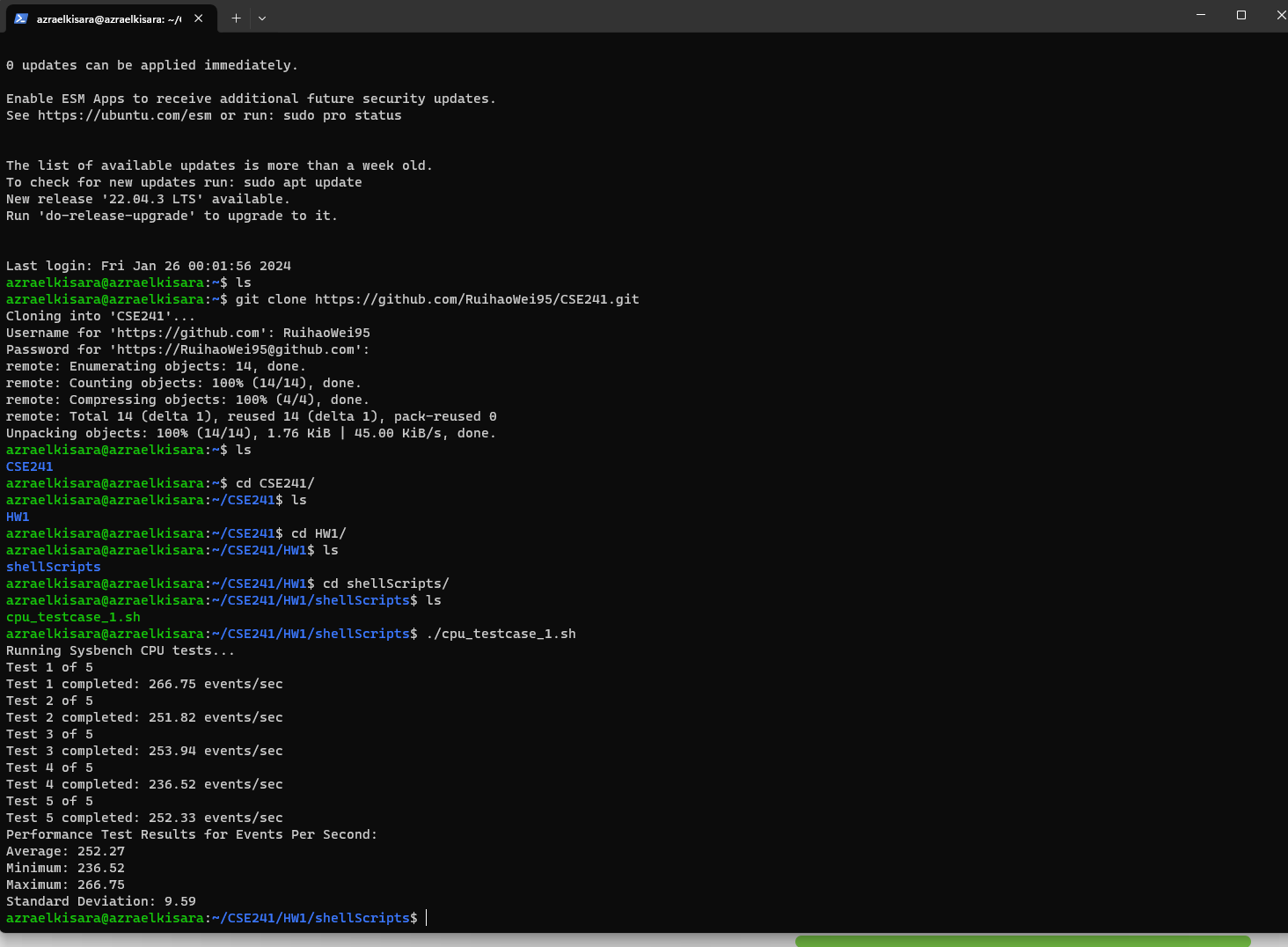
1. Sysbench test cases:
   1. CPU test case 1: --cpu-max-prime=20000 --time=20 run
   2. CPU test case 2: --cpu-max-prime=80000 --time=20 run
   3. Memory test case 1: --memory-block-size=1K
   4. Memory test case 2: --memory-block-size=2K
   5. FileIO test case 1: --file-total-size=1G --file-test-mode=rndrw
   6. FileIO test case 2: --file-total-size=2G --file-test-mode=rndrw
2. Experiment with qcow2 image:

**Proof of experiment**

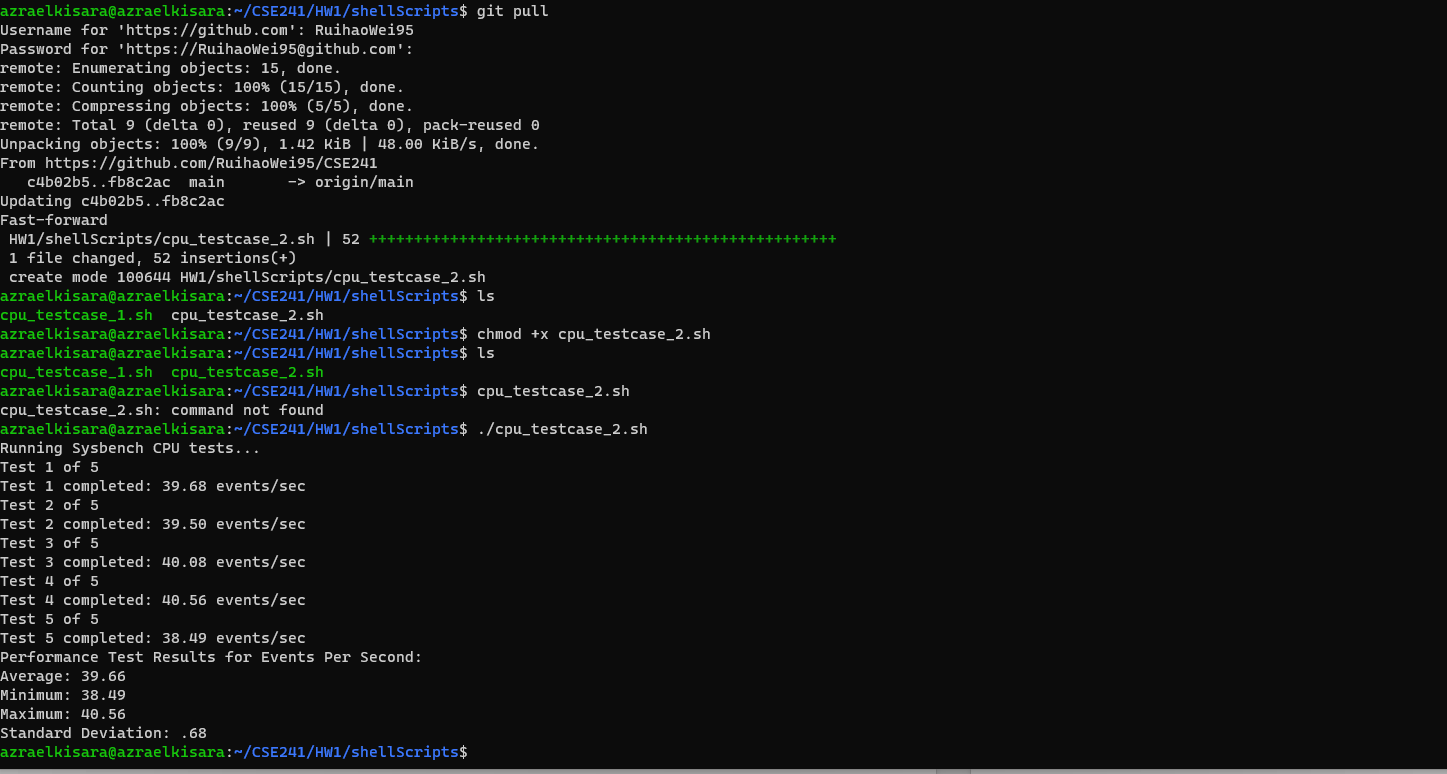
* 1. cpu: 2, RAM: 2048



CPU test case 1



CPU test case 2

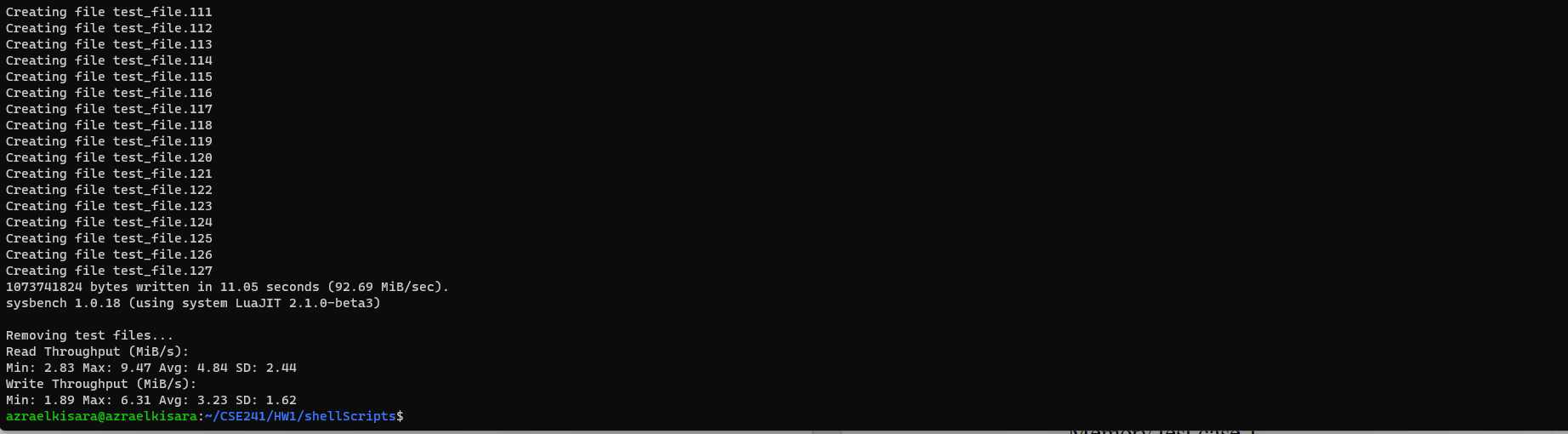
Memory test case 1



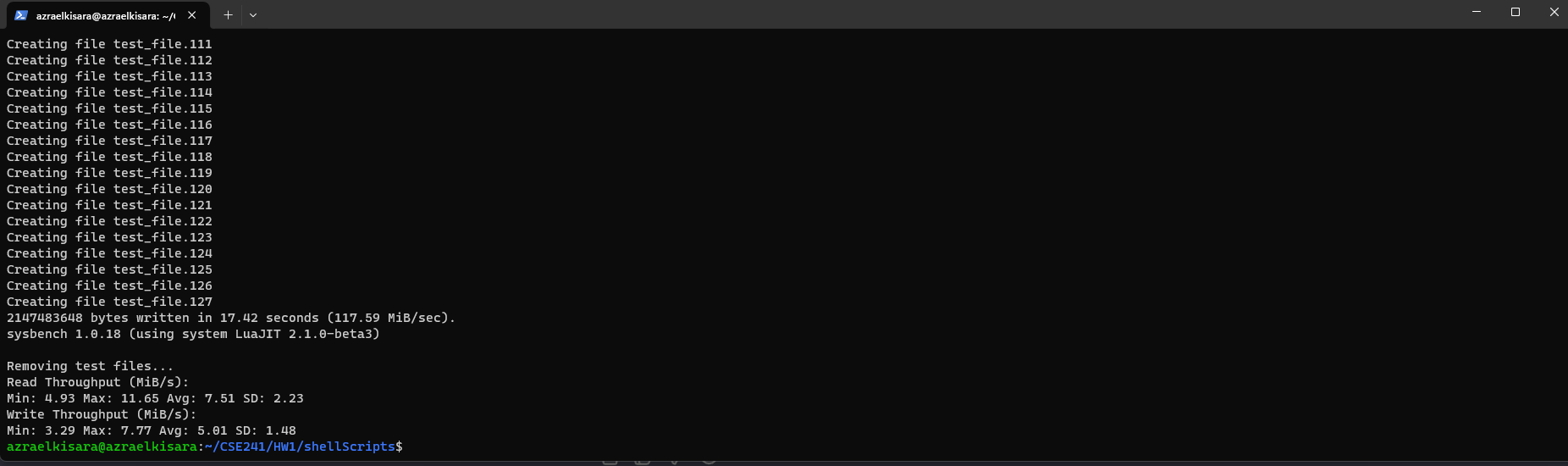
Memory test case 2



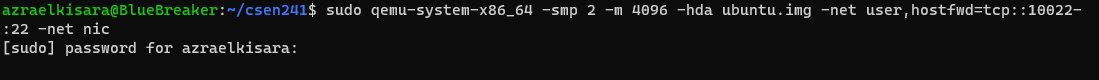
FileIO test case 1



FileIO test case 2



* 1. cpu: 2, RAM: 4096



CPU test case 1



CPU test case 2



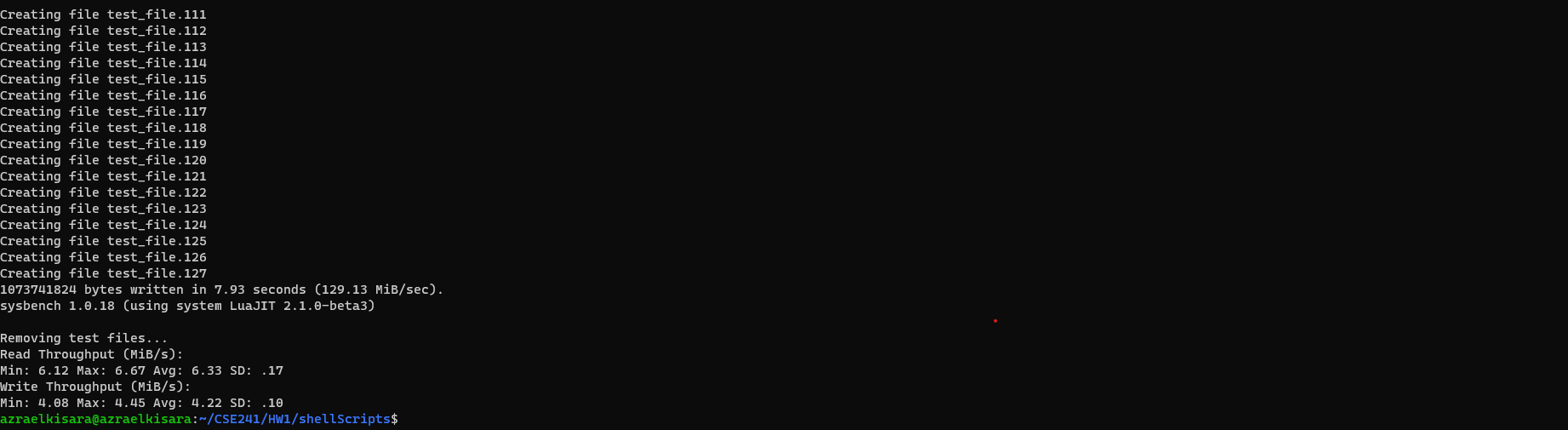
Memory test case 1



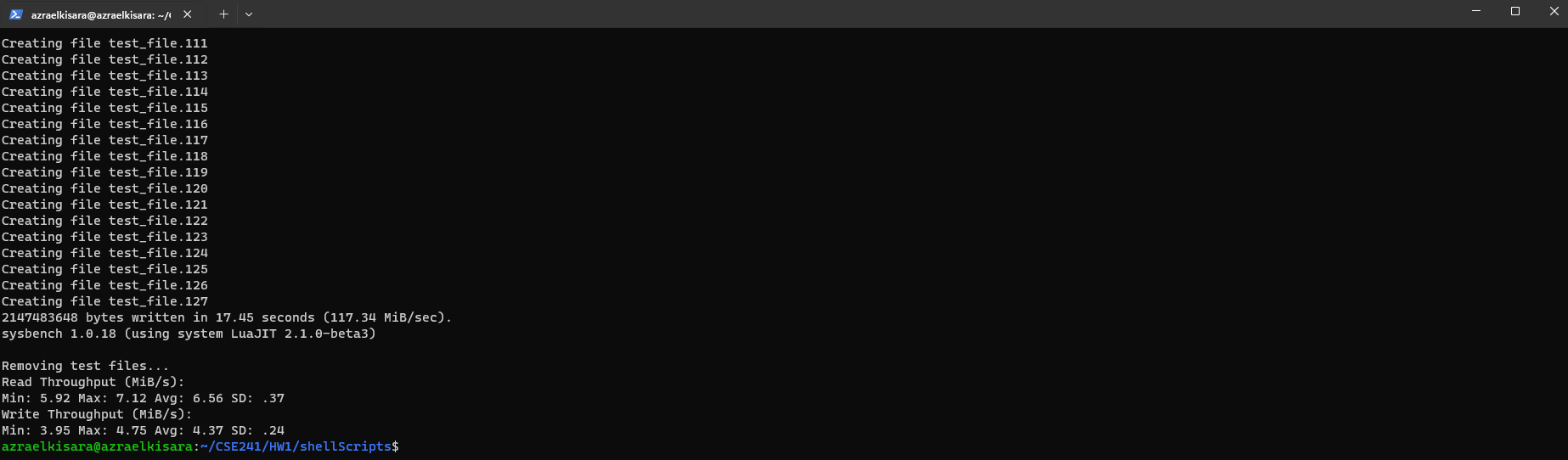
Memory test case 2



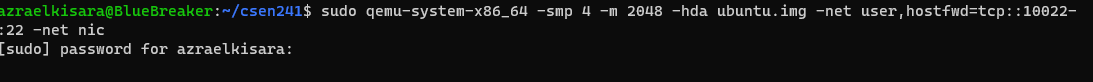
FileIO test case 1



FileIO test case 2



* 1. cpu: 4, RAM: 2048



CPU test case 1



CPU test case 2



Memory test case 1



Memory test case 2



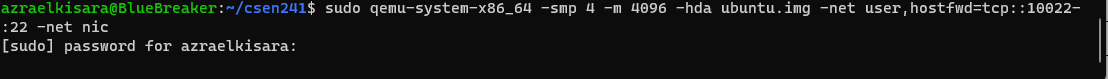
FileIO test case 1



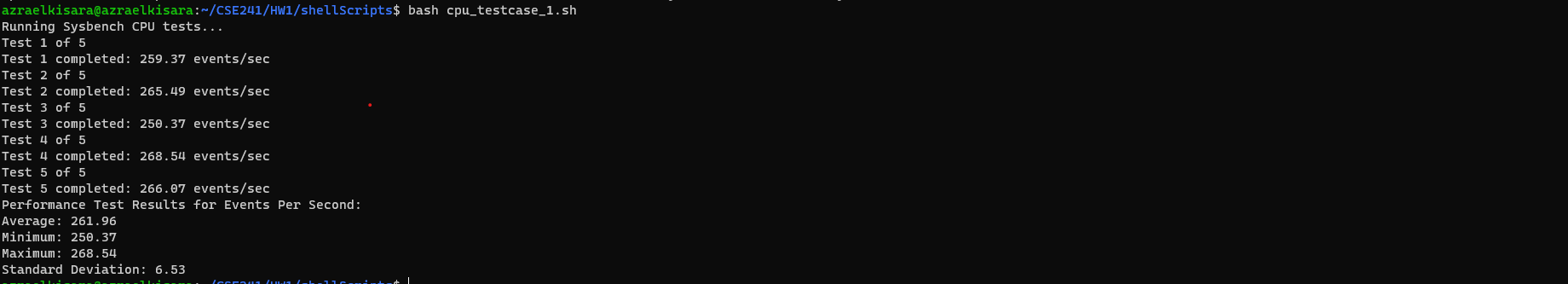
FileIO test case 2



* 1. cpu: 4, RAM: 4096



CPU test case 1



CPU test case 2



Memory test case 1



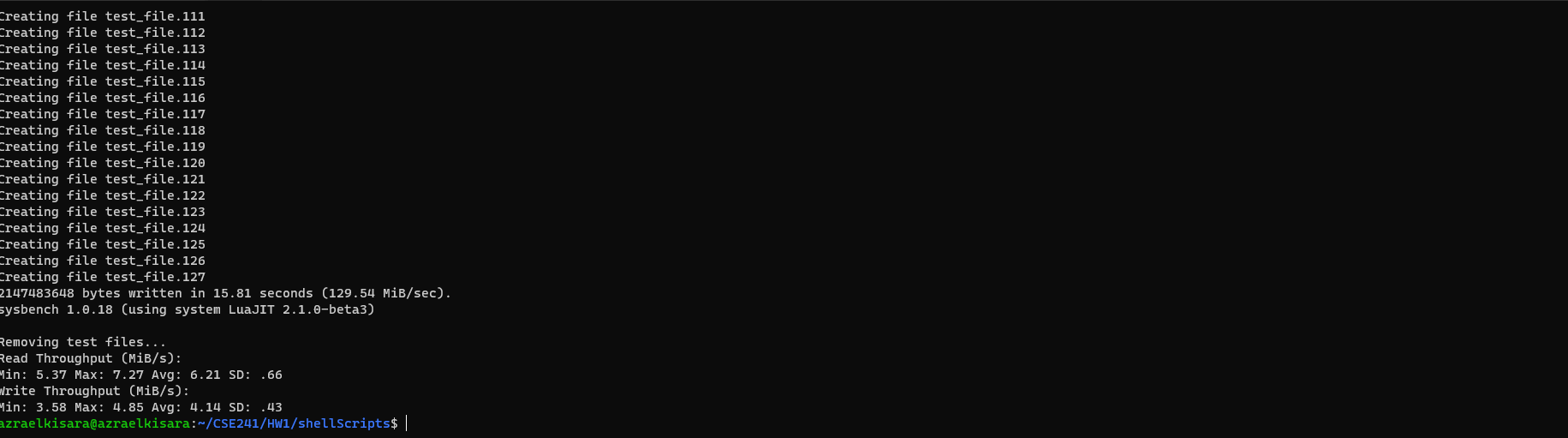
Memory test case 2



FileIO test case 1



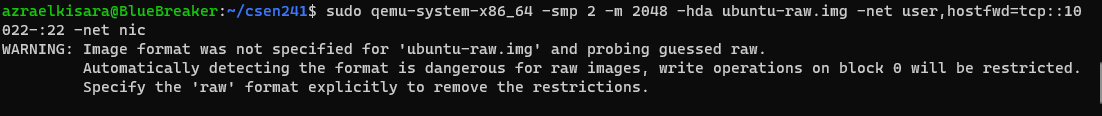
FileIO test case 2



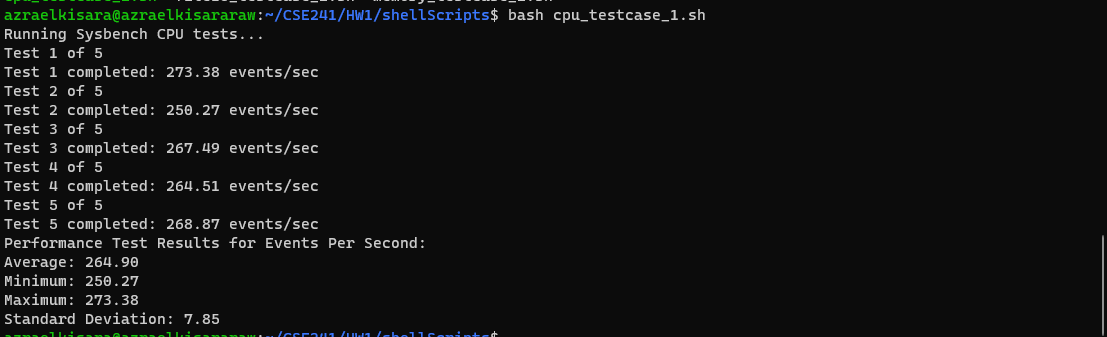
1. Experiment with raw image:

**Proof of experiment**

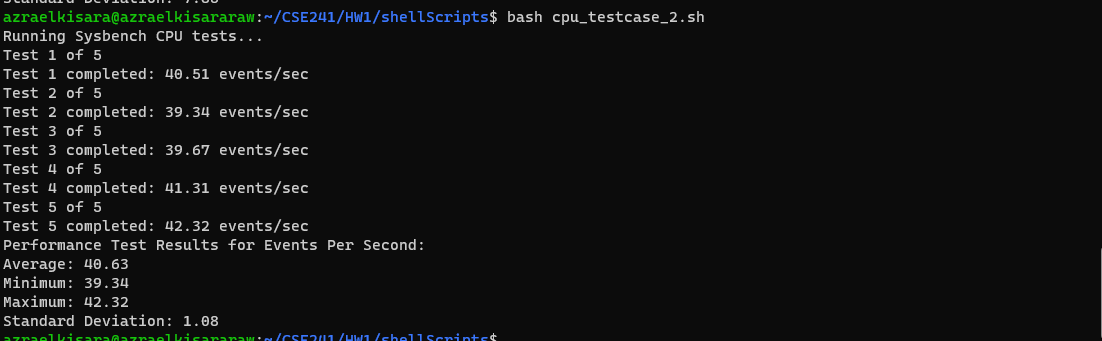
* 1. cpu: 2, RAM: 2048



CPU test case 1



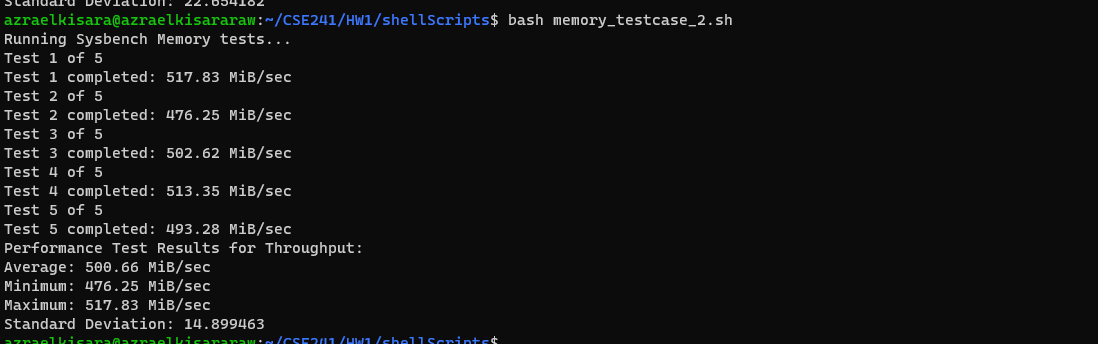
CPU test case 2



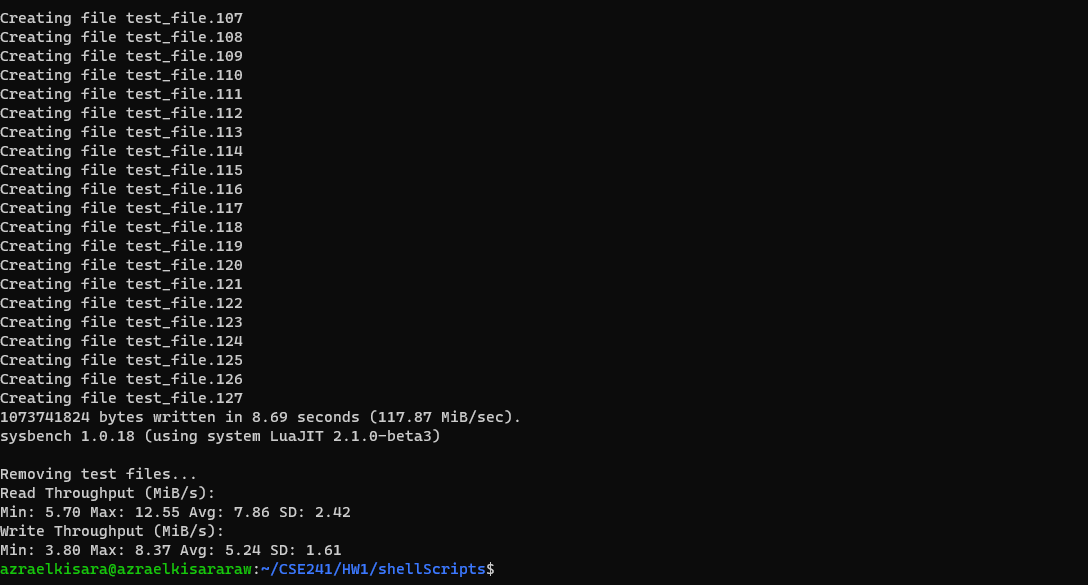
Memory test case 1



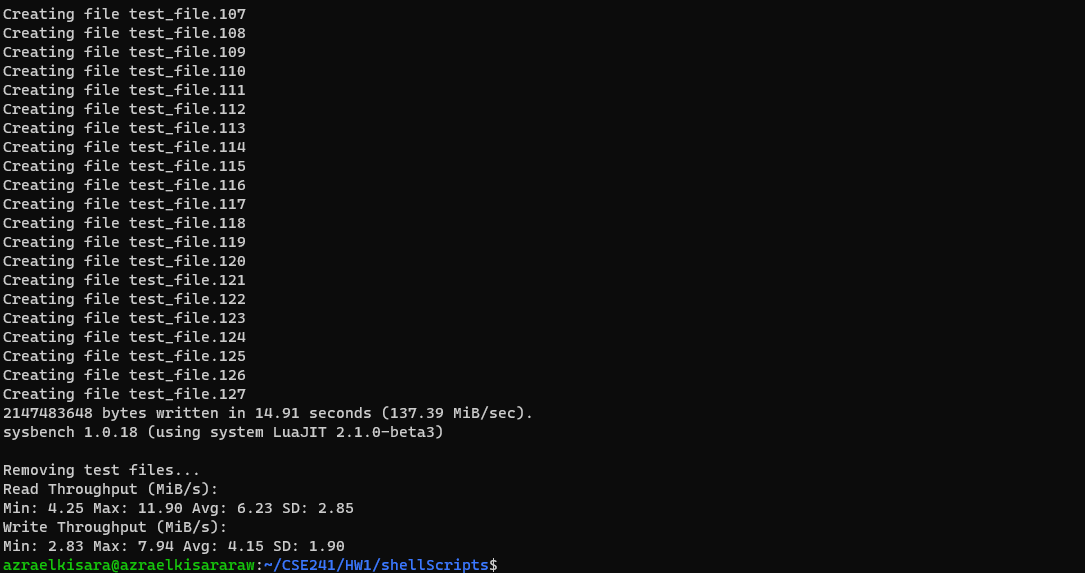
Memory test case 2



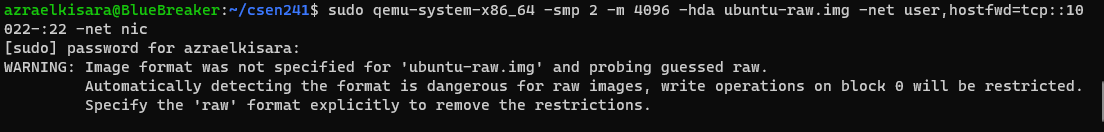
FileIO test case 1



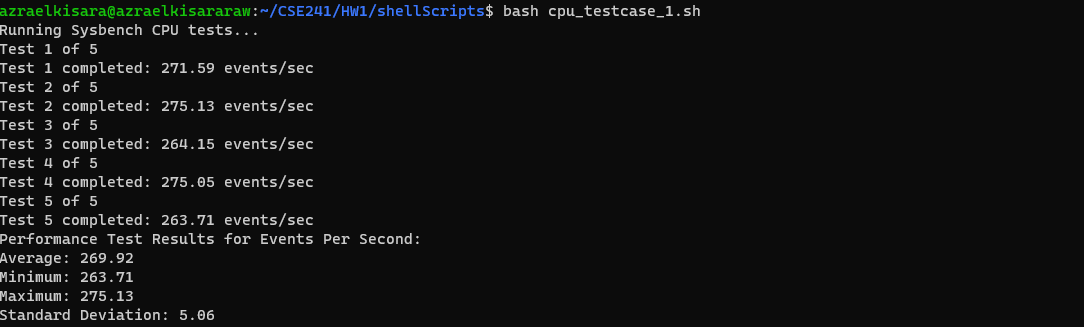
FileIO test case 2



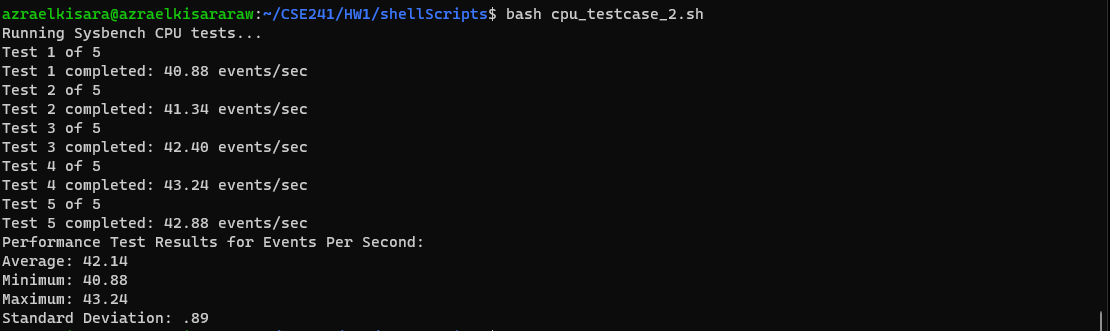
* 1. cpu: 2, RAM: 4096



CPU test case 1



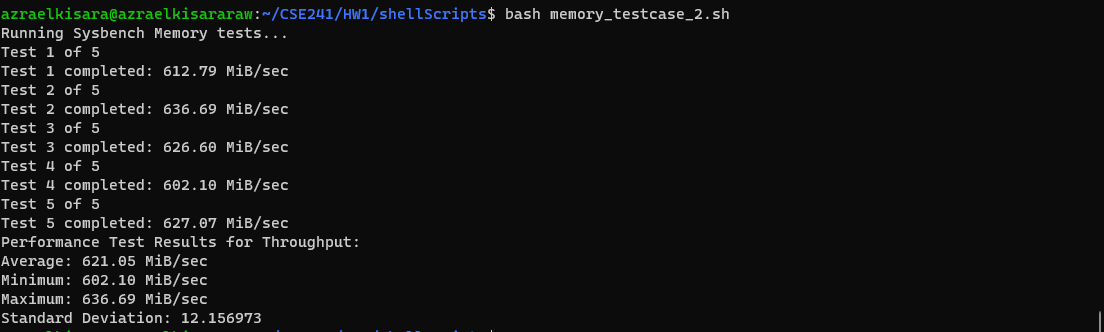
CPU test case 2



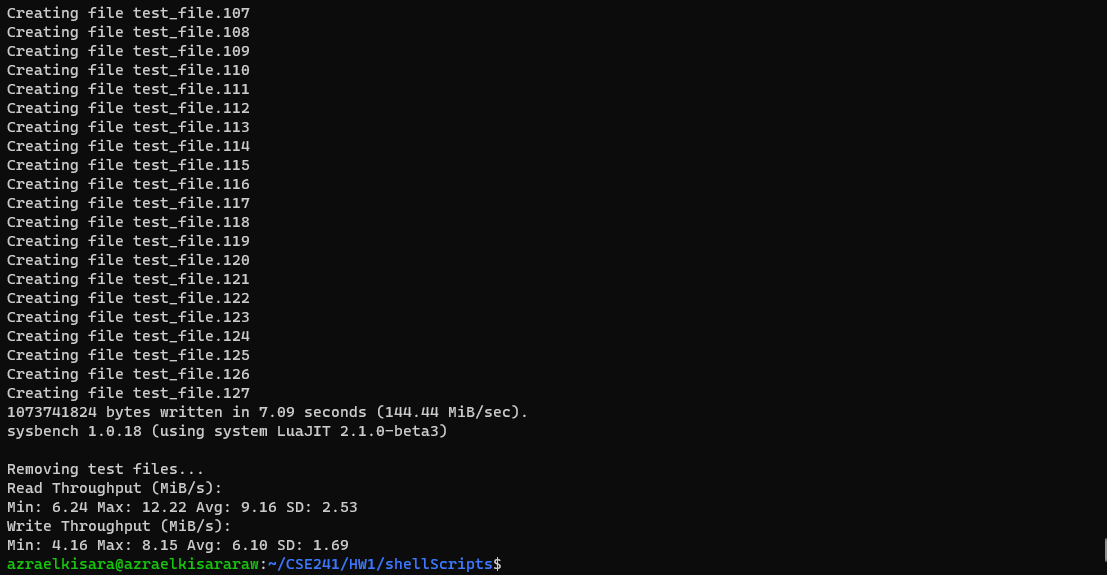
Memory test case 1



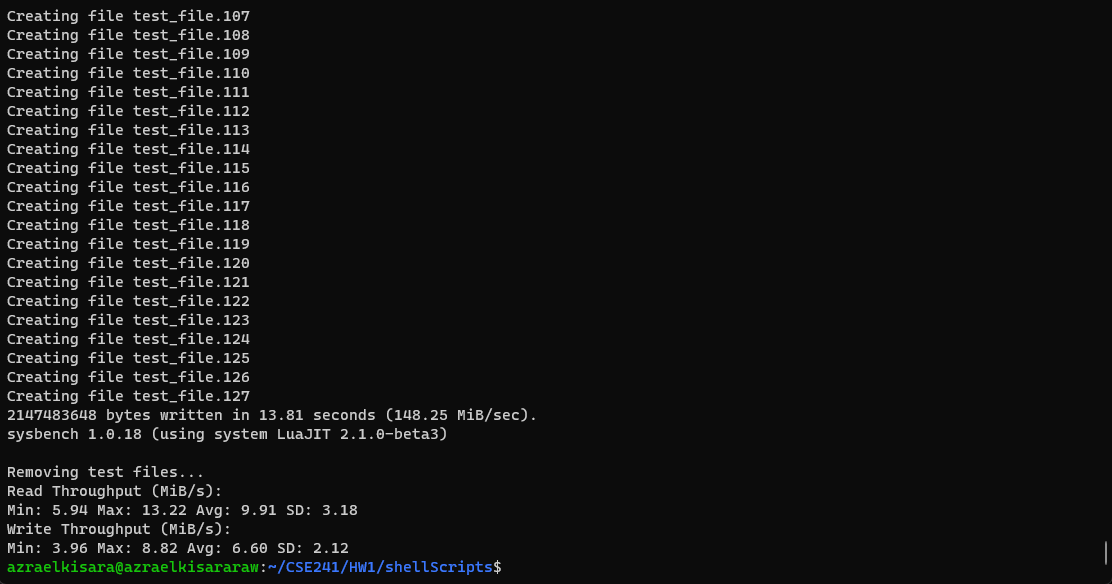
Memory test case 2



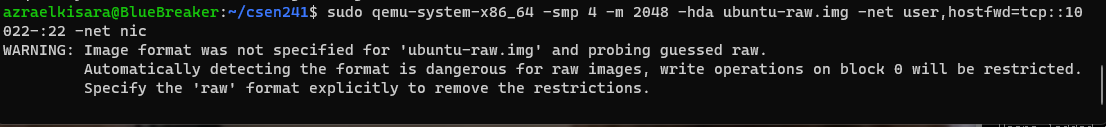
FileIO test case 1



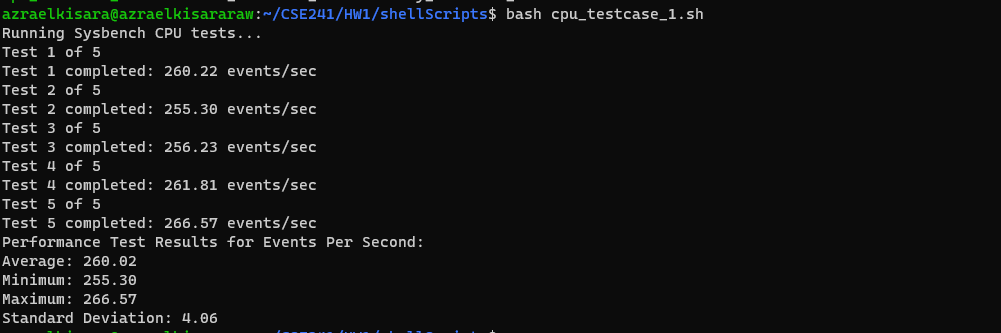
FileIO test case 2



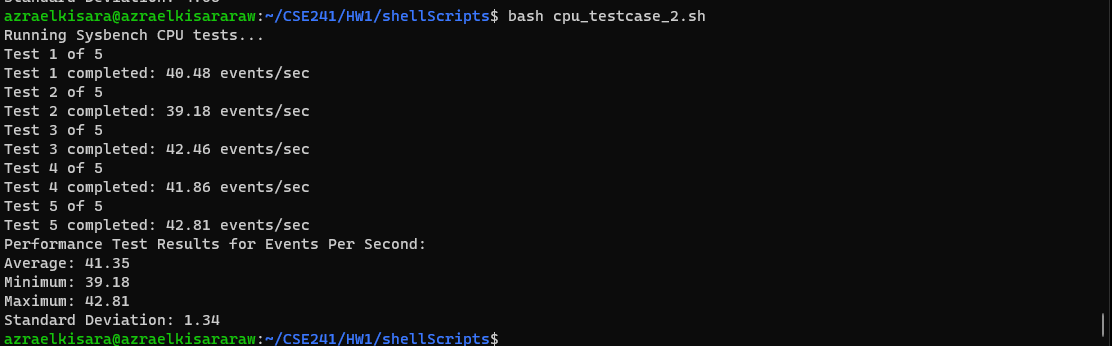
* 1. cpu: 4, RAM: 2048



CPU test case 1



CPU test case 2



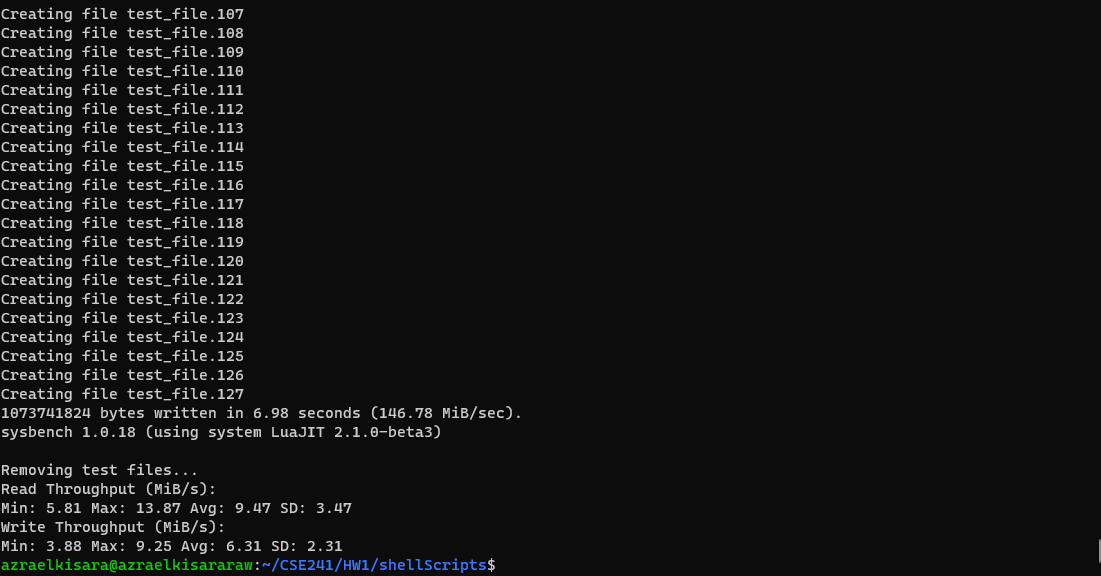
Memory test case 1



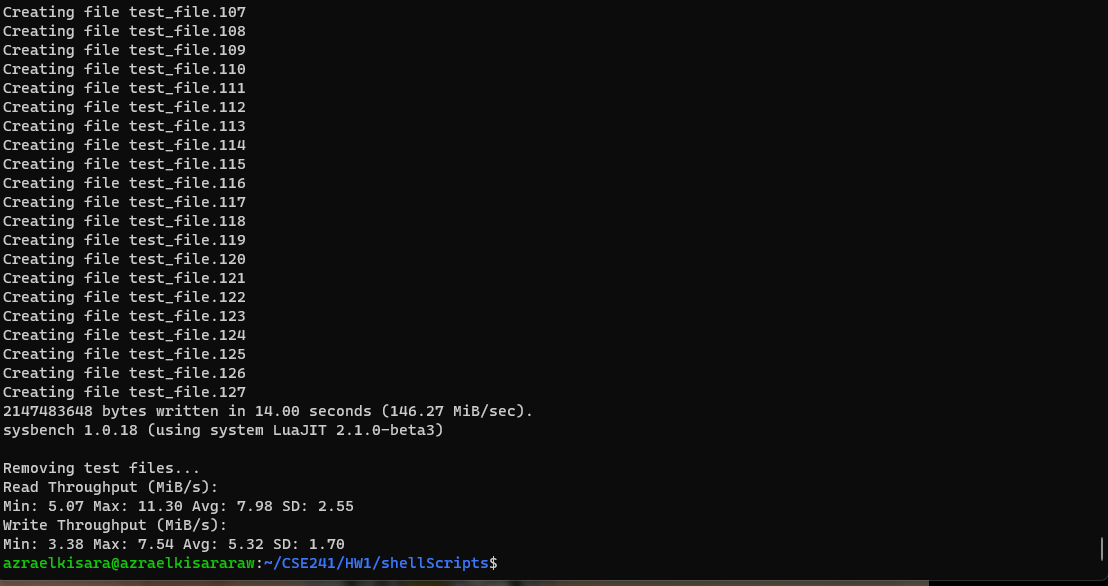
Memory test case 2



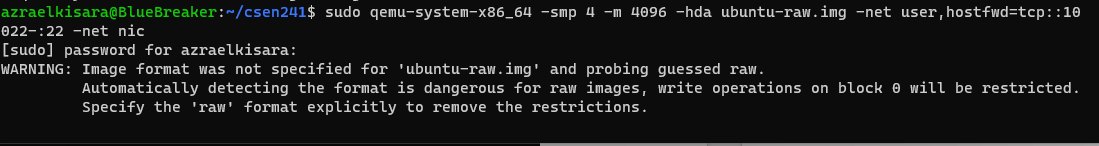
FileIO test case 1



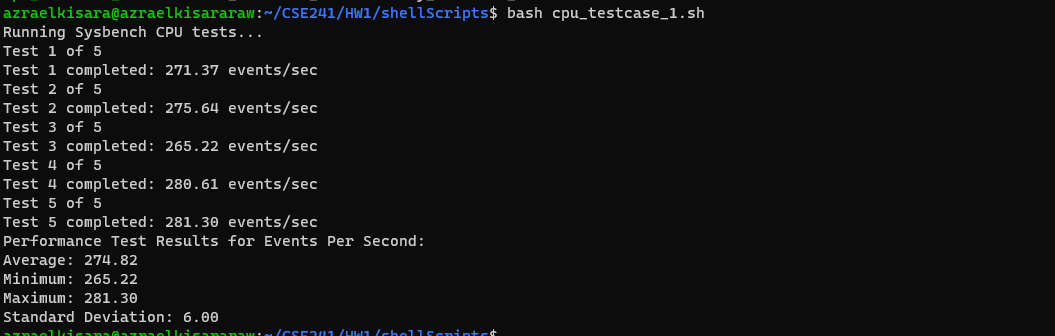
FileIO test case 2



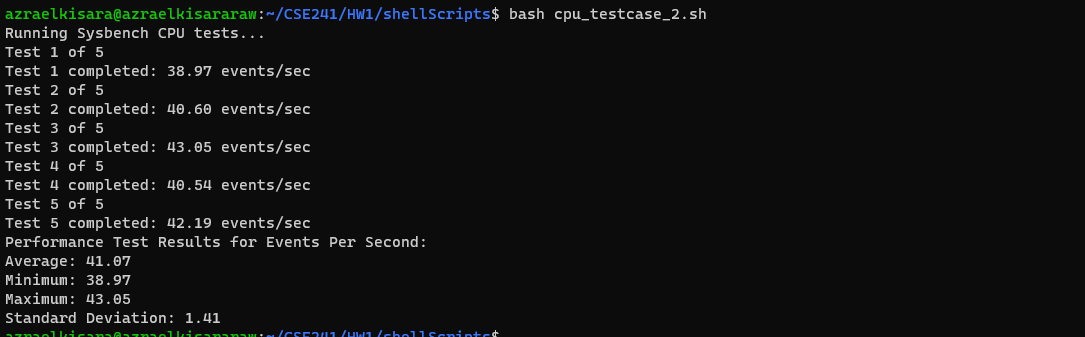
* 1. cpu: 4, RAM: 4096



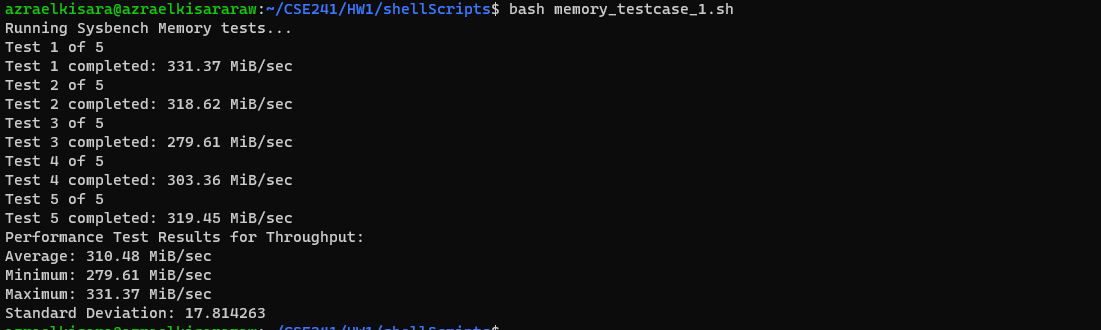
CPU test case 1



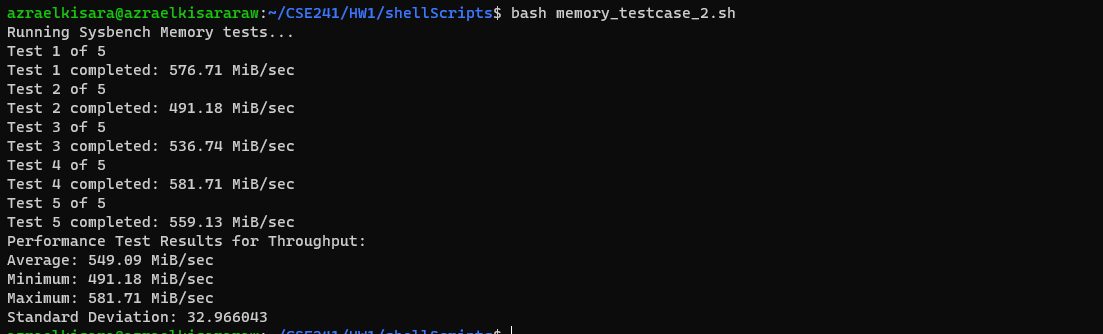
CPU test case 2



Memory test case 1



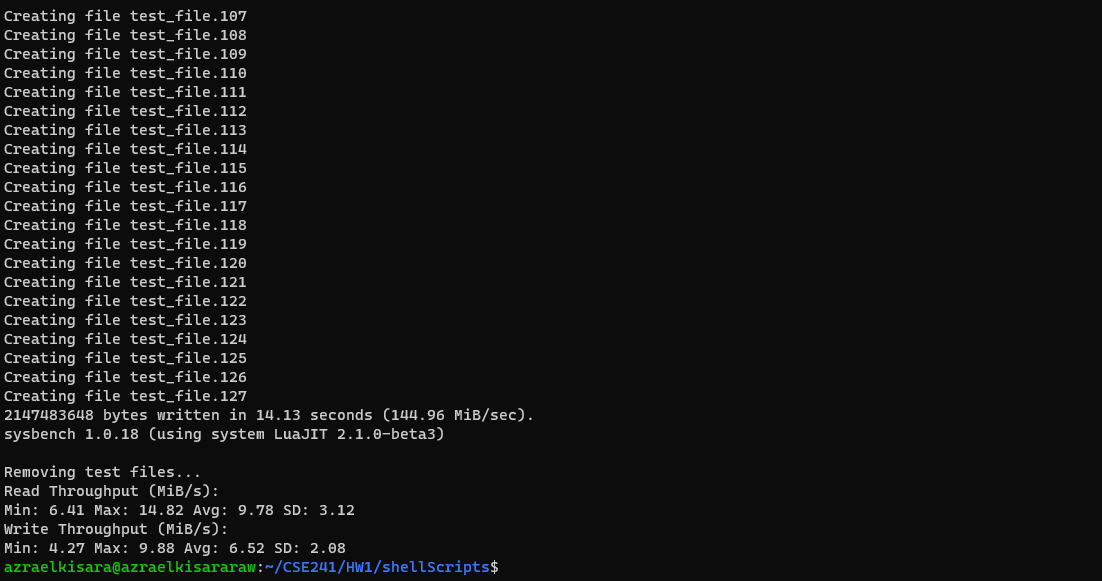
Memory test case 2



FileIO test case 1



FileIO test case 2



**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”

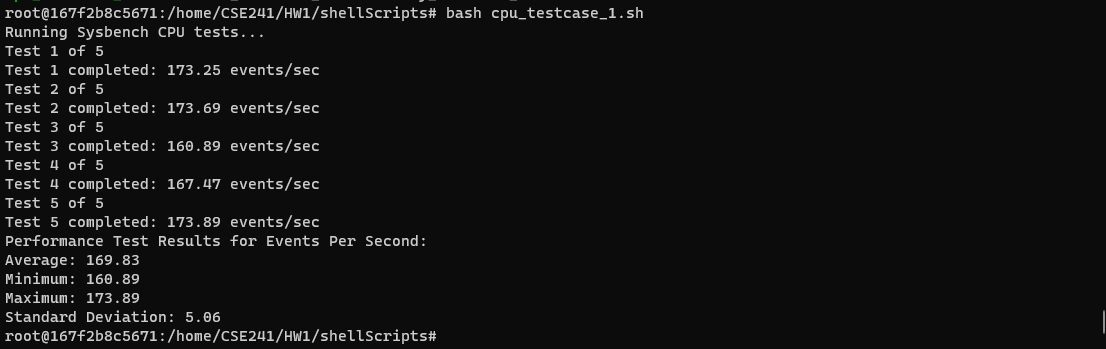
1. Experiment with docker image:

**Proof of experiment**

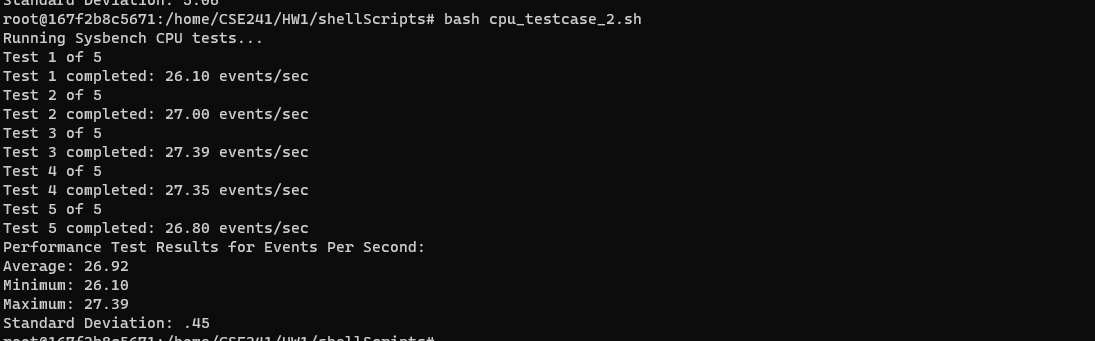
* 1. cpu: 2, RAM: 2048



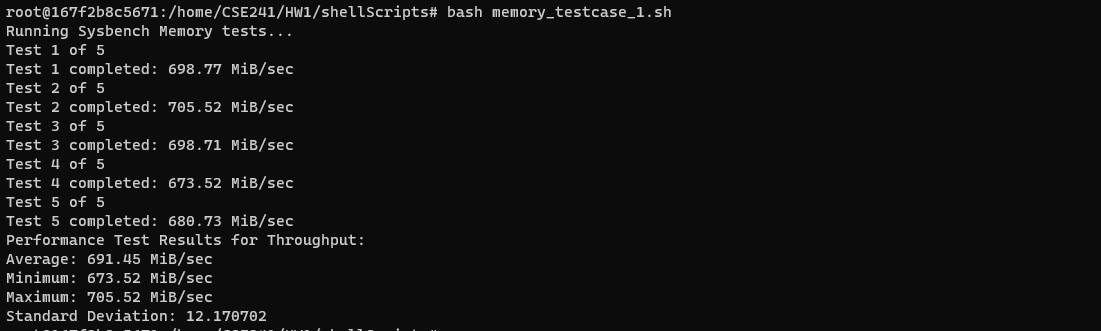
CPU test case 1



CPU test case 2



Memory test case 1



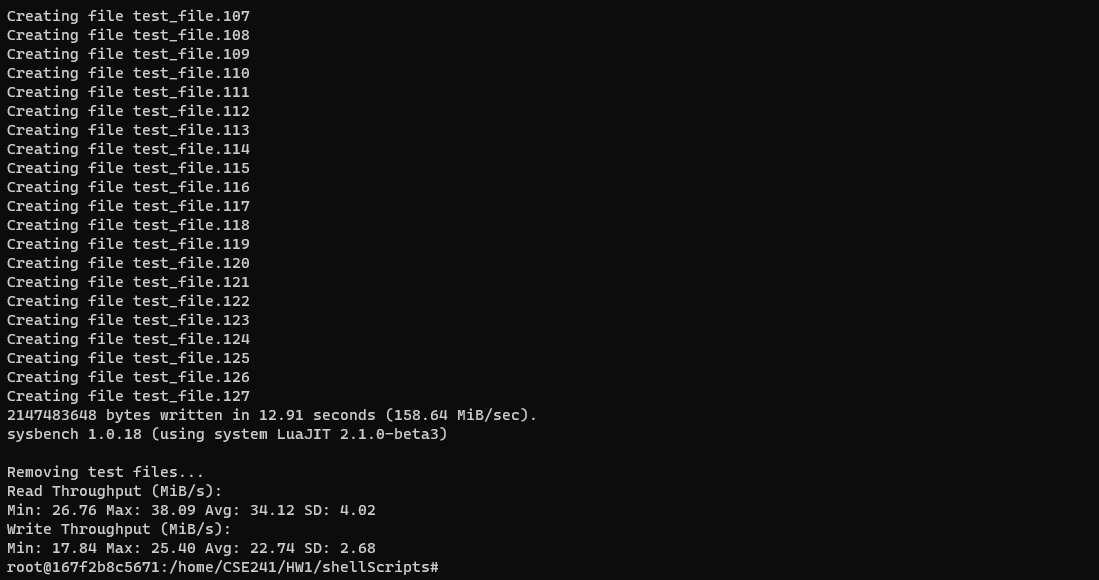
Memory test case 2



FileIO test case 1



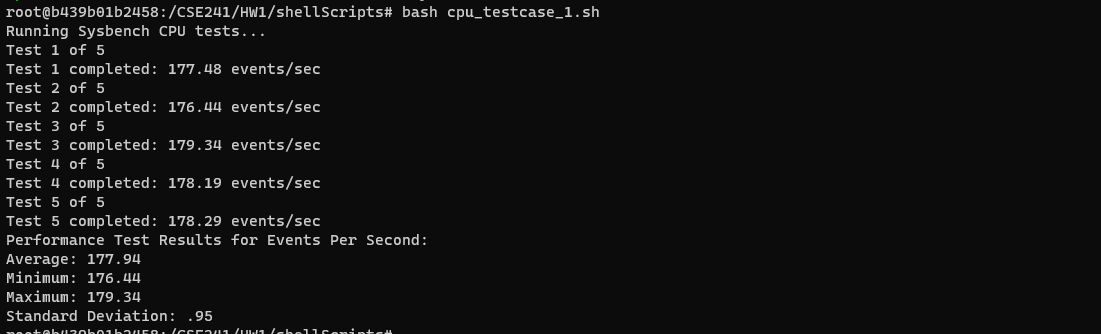
FileIO test case 2



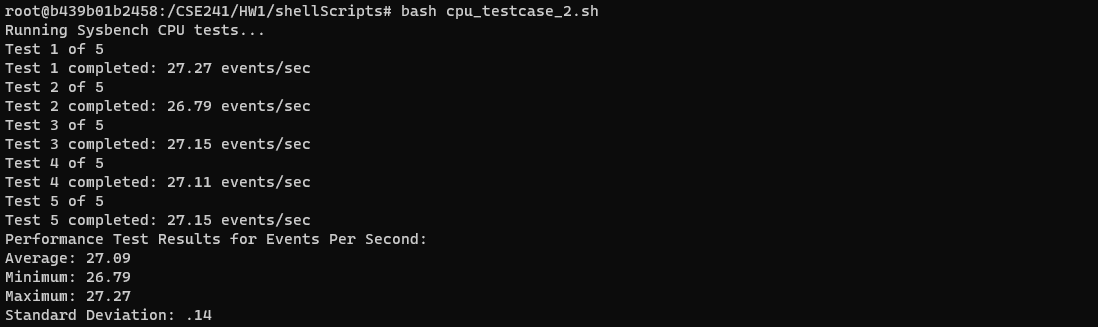
* 1. cpu: 2, RAM: 4096



CPU test case 1



CPU test case 2



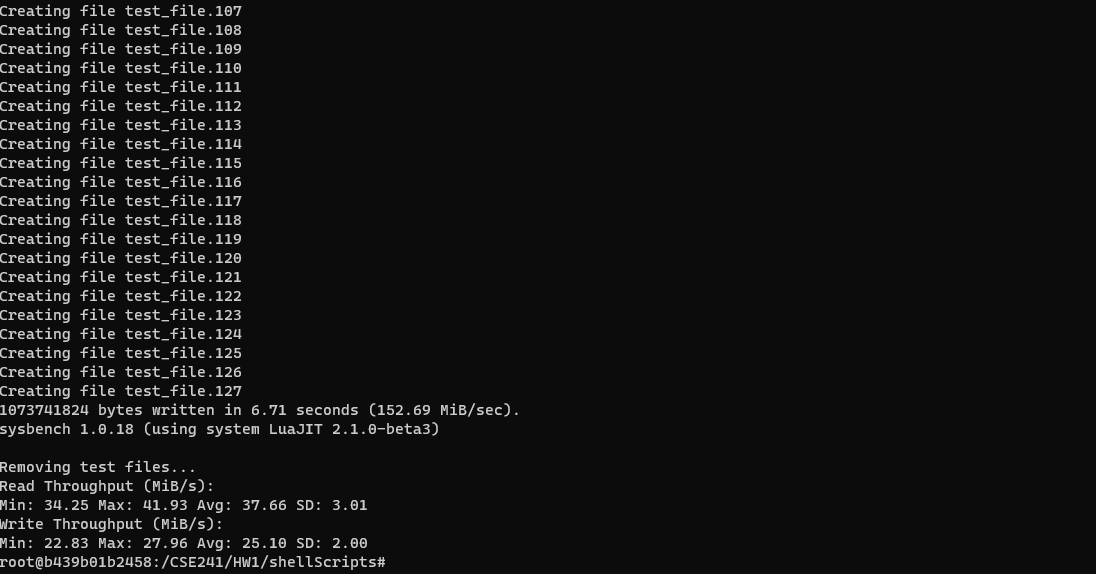
Memory test case 1



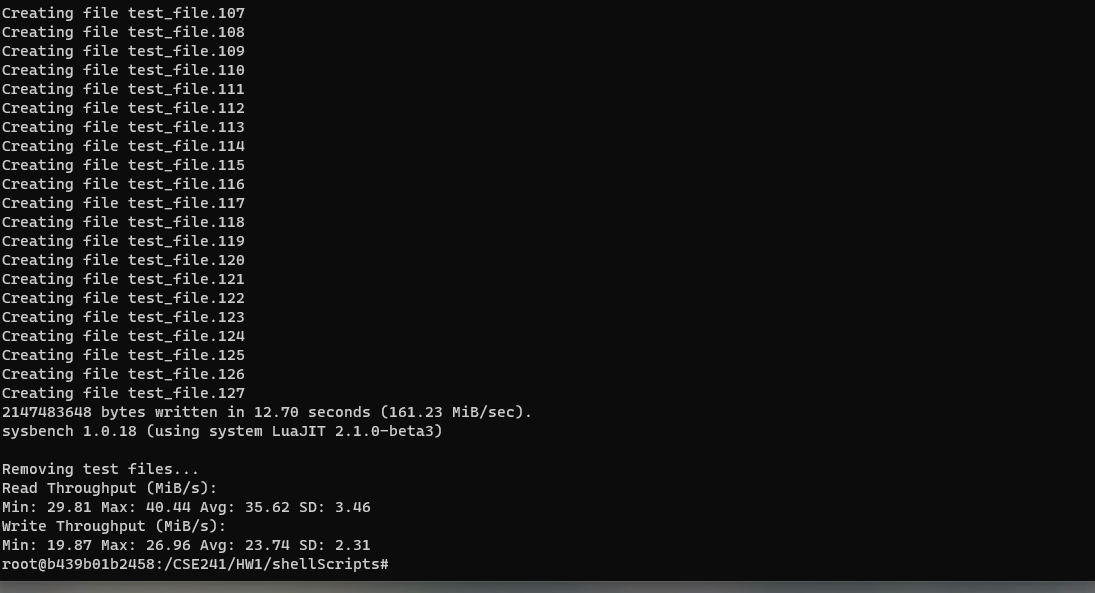
Memory test case 2



FileIO test case 1



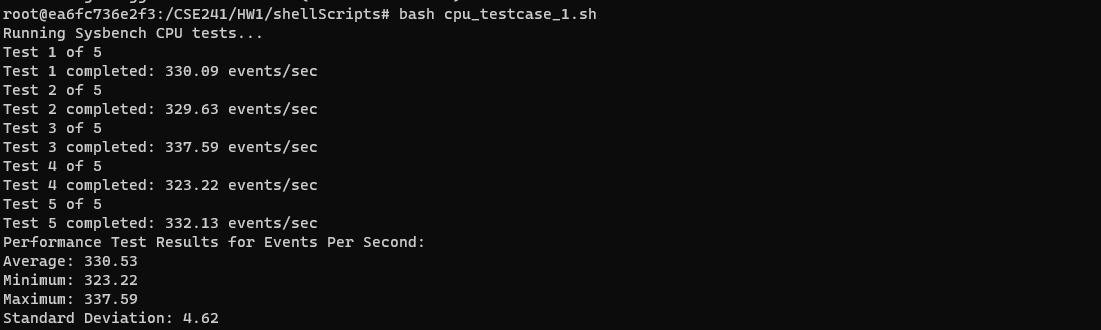
FileIO test case 2



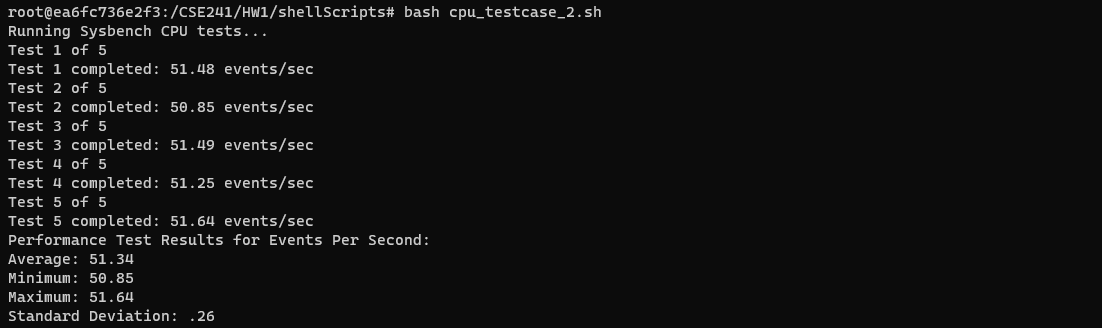
* 1. cpu: 4, RAM: 2048



CPU test case 1



CPU test case 2



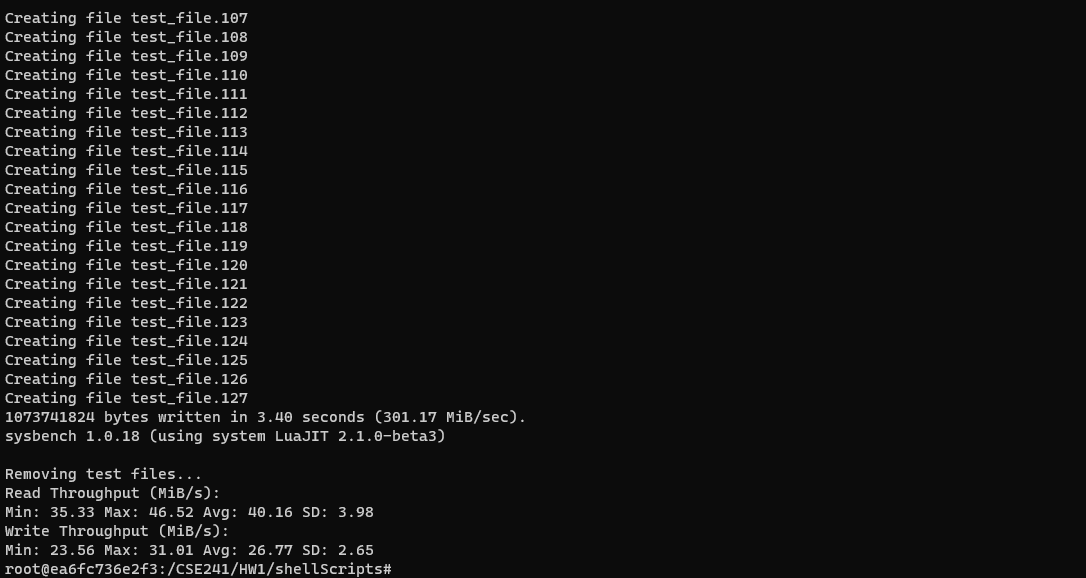
Memory test case 1



Memory test case 2



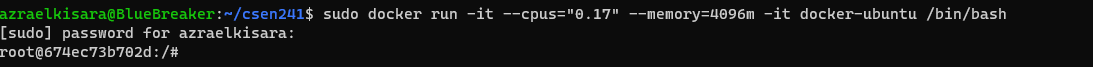
FileIO test case 1



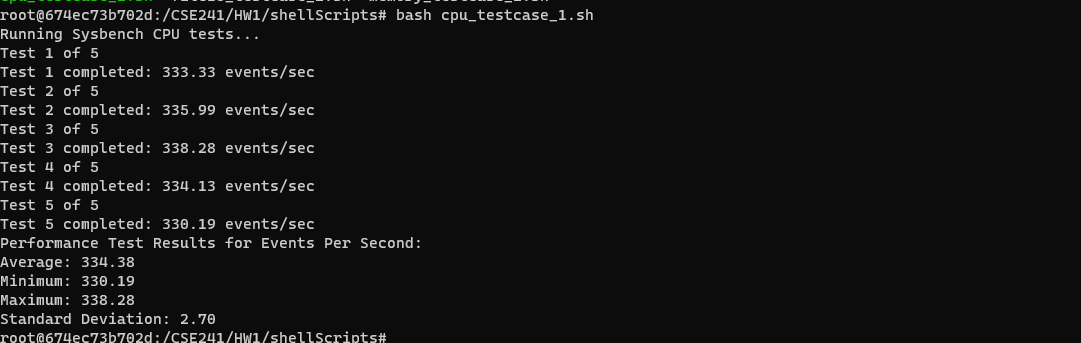
FileIO test case 2



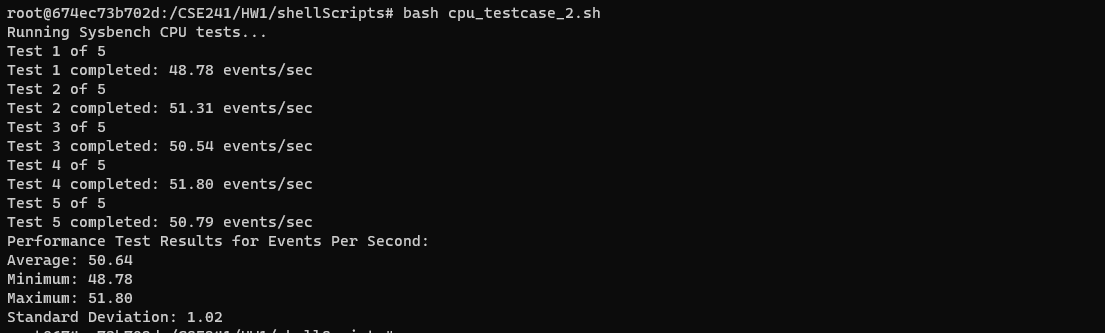
* 1. cpu: 4, RAM: 4096



CPU test case 1



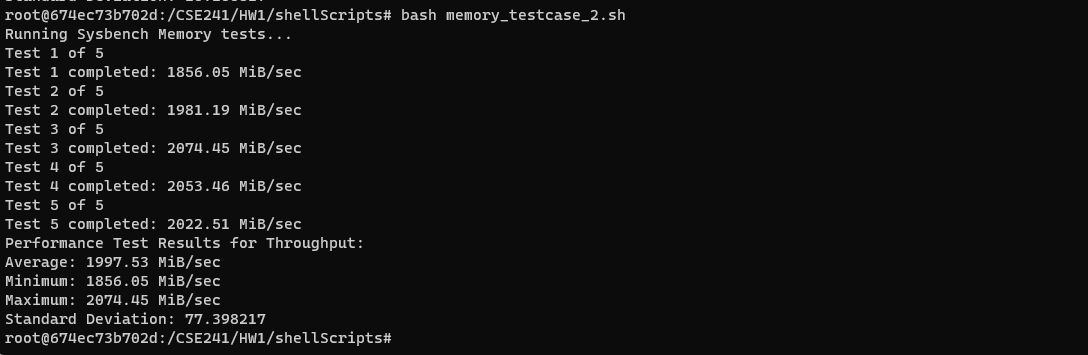
CPU test case 2



Memory test case 1



Memory test case 2



FileIO test case 1



FileIO test case 2



**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 size | 2G | 17.84 | 25.40 | 22.74 | 2.68 |
| 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**