

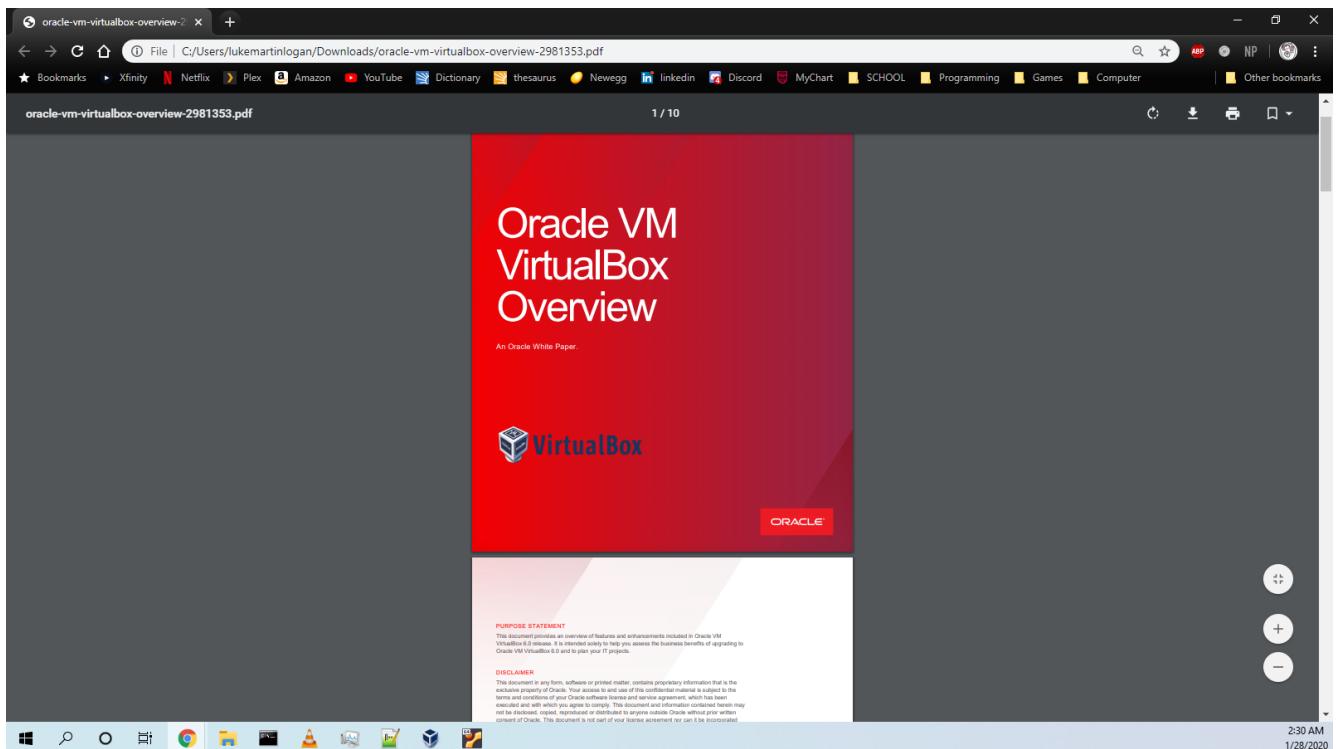
HW1

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1/30/2020

1 Question 1

(a) Read VirtualBox whitepaper



(b) Download VirtualBox

Here you will find links to VirtualBox binaries and its source code.

VirtualBox binaries

By downloading, you agree to the terms and conditions of the respective license.

If you're looking for the latest VirtualBox 6.0 packages, see [VirtualBox 6.0 builds](#). Please also use version 6.0 if you need to run VMs with software virtualization, as this has been discontinued in 6.1. Version 6.0 will remain supported until July 2020.

If you're looking for the latest VirtualBox 5.2 packages, see [VirtualBox 5.2 builds](#). Please also use version 5.2 if you still need support for 32-bit hosts, as this has been discontinued in 6.0. Version 5.2 will remain supported until July 2020.

VirtualBox 6.1.2 platform packages

- Windows hosts
- OS X hosts
- Linux distributions
- Solaris hosts

The binaries are released under the terms of the GPL version 2.

See the [changelog](#) for what has changed.

You might want to compare the checksums to verify the integrity of downloaded packages. *The SHA256 checksums should be favored as the MD5 algorithm must be treated as insecure!*

- [SHA256 checksums](#), [MD5 checksums](#)

Note: After upgrading VirtualBox it is recommended to upgrade the guest additions as well.

VirtualBox 6.1.2 Oracle VM VirtualBox Extension Pack

- All supported platforms

Support for USB 2.0 and USB 3.0 devices, VirtualBox RDP, disk encryption, NVMe and PXE boot for Intel cards. See [this chapter from the User Manual](#) for an introduction to this Extension Pack. The Extension Pack binaries are released under the [VirtualBox Personal Use and Evaluation License \(PUEL\)](#). Please install the same version extension pack as your installed version of VirtualBox.

(c) Install virtualbox

Thank you for downloading Ubuntu

Ubuntu.com/download/desktop/thank-you?country=US&version=18.04.3&architecture=amd64

Canonical

Enterprise Developer Community Download

Oracle VM VirtualBox 6.1.2 installation is complete.

Click the Finish button to exit the Setup Wizard.

Version 6.1.2

< Back Finish Cancel

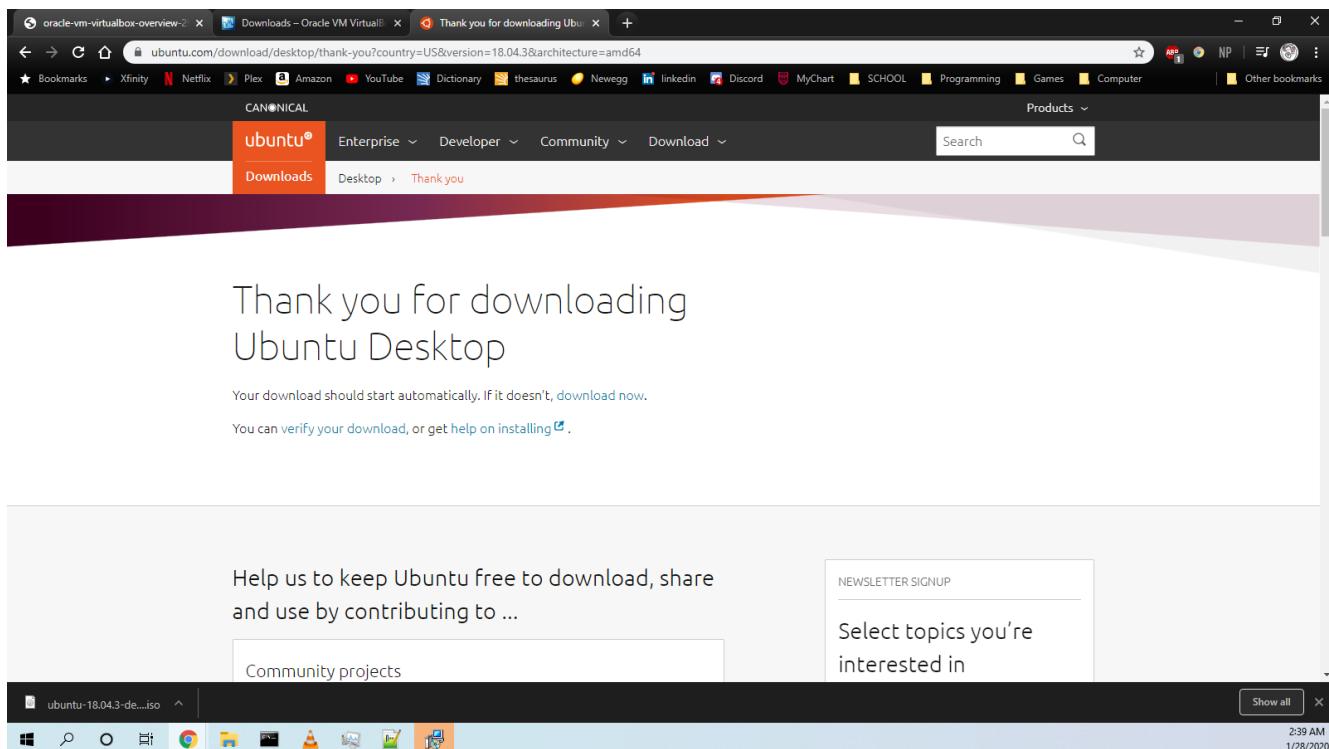
Help us to keep Ubuntu free to download, share and use by contributing to ...

Community projects

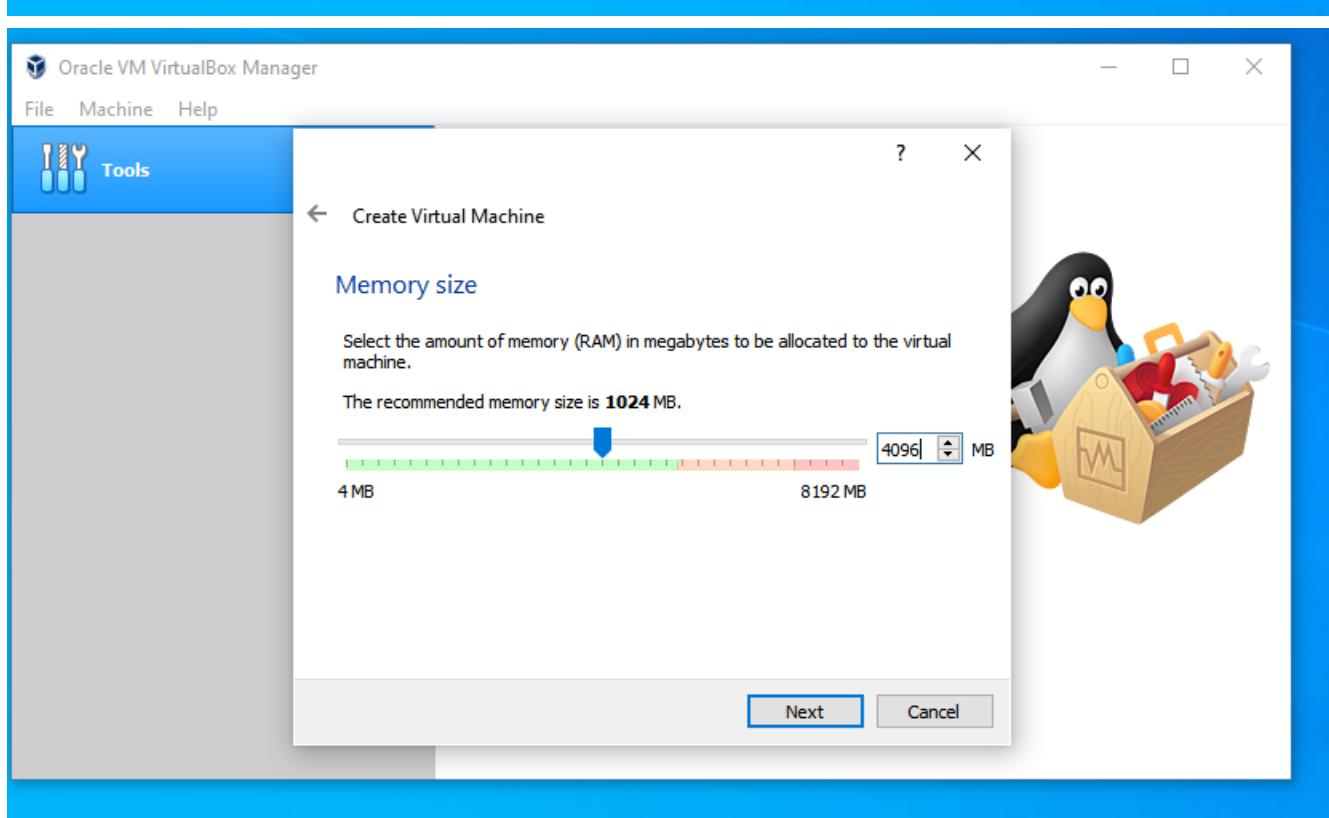
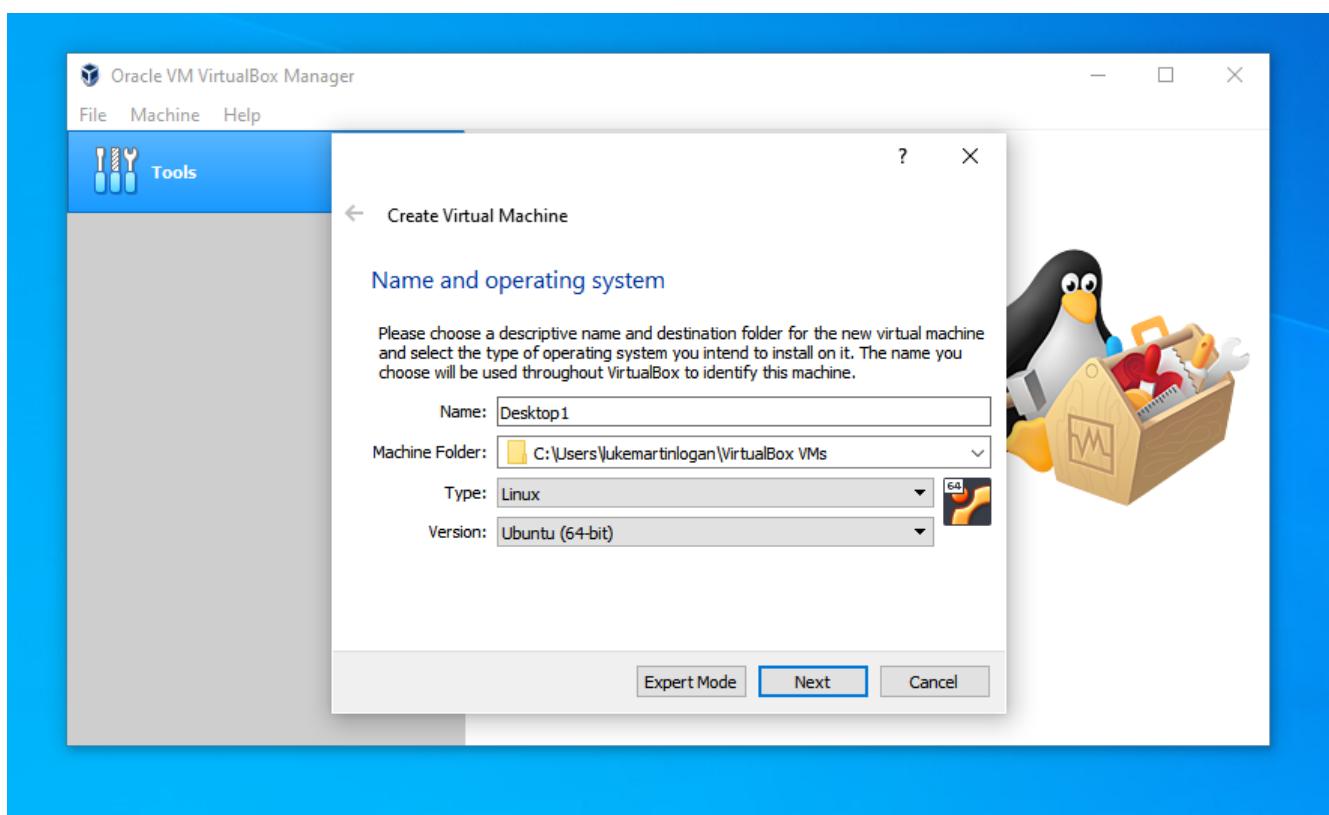
NEWSLETTER SIGNUP

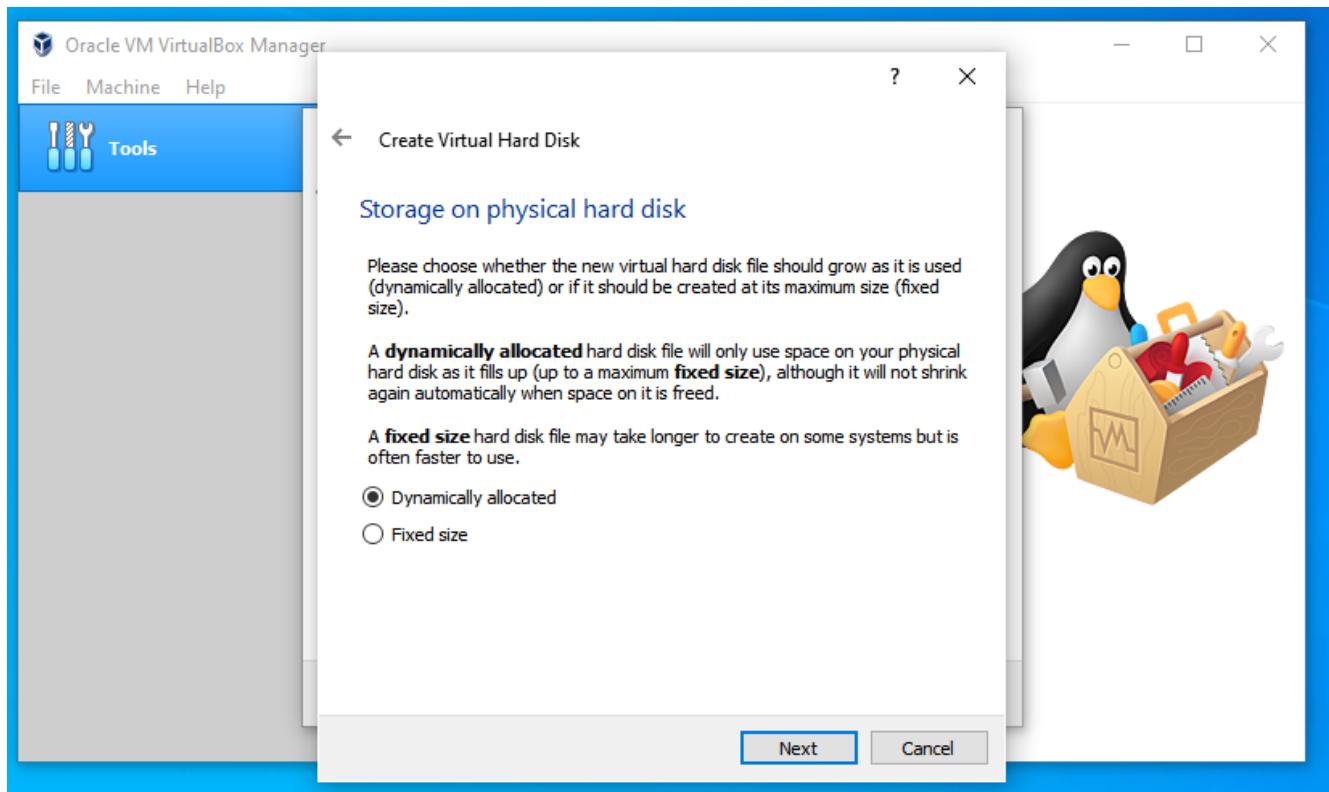
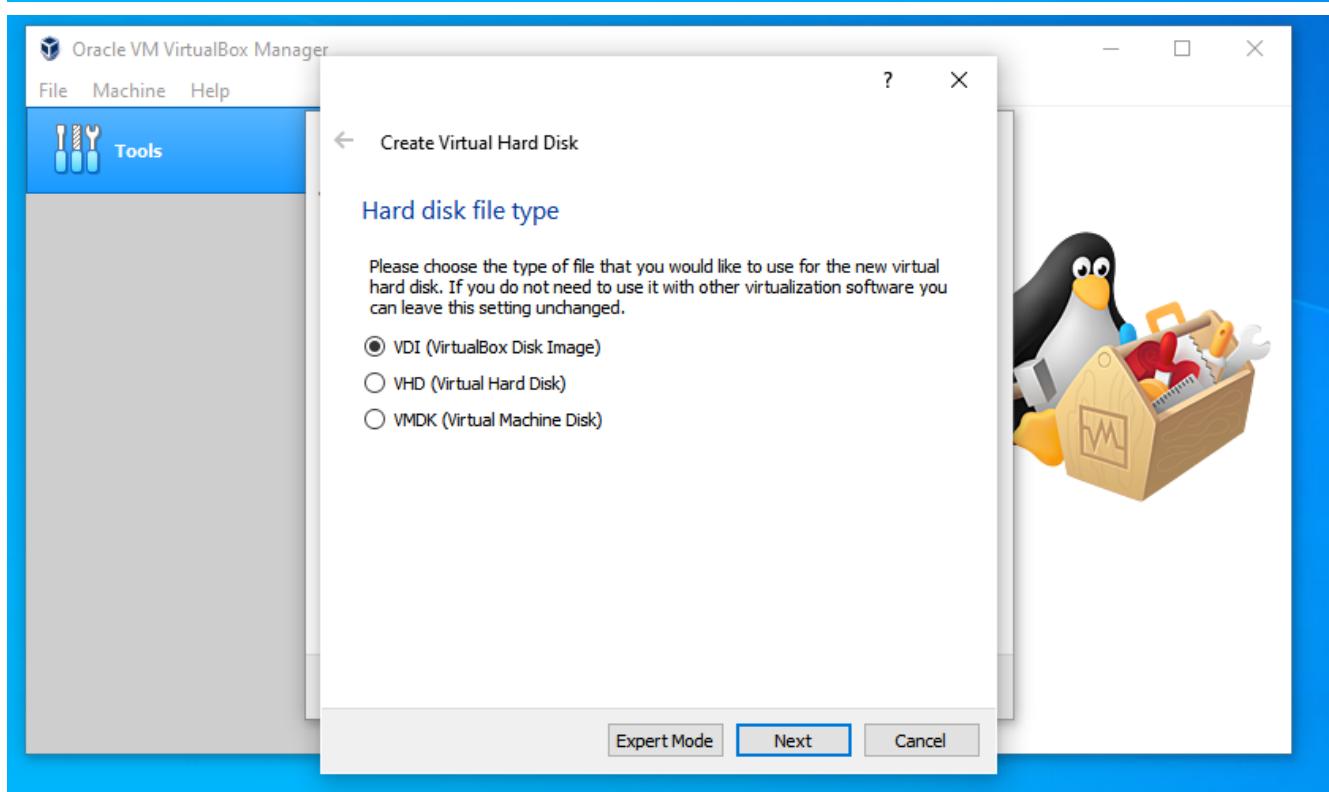
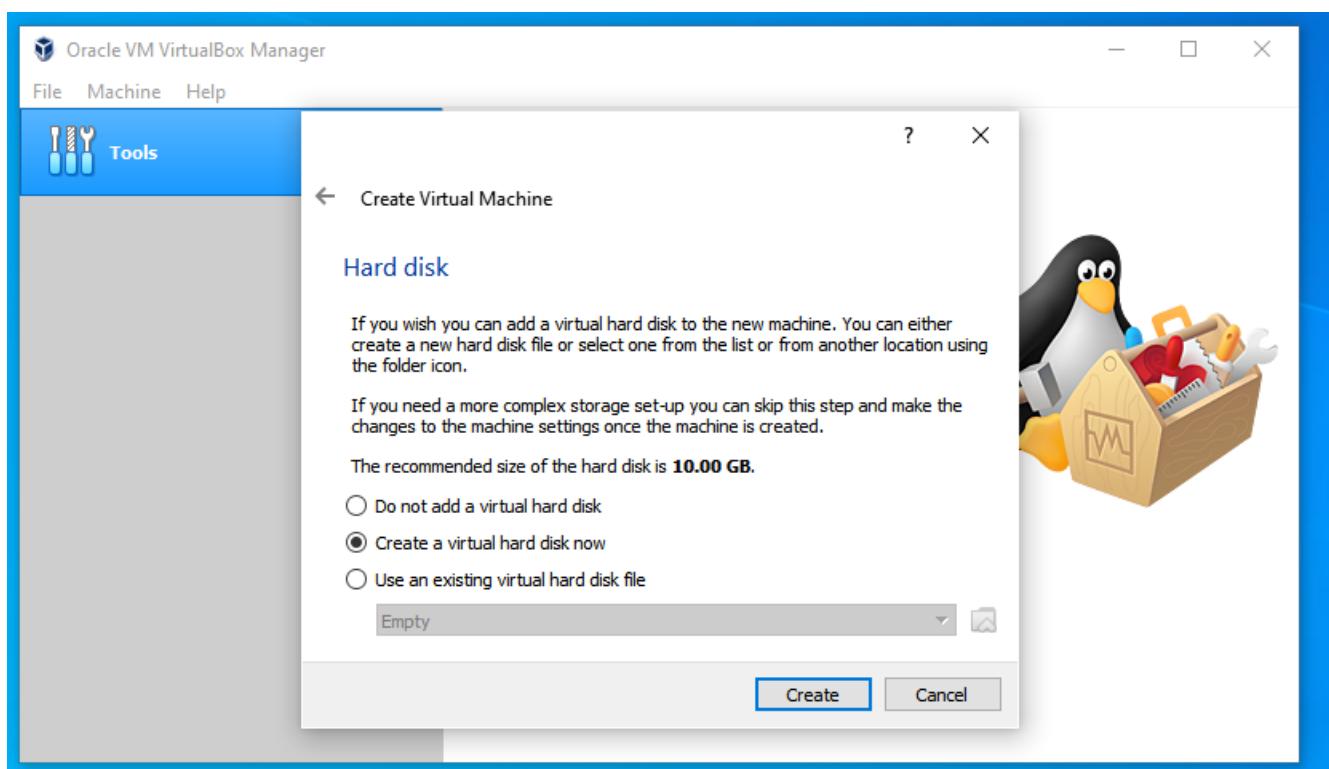
Select topics you're interested in

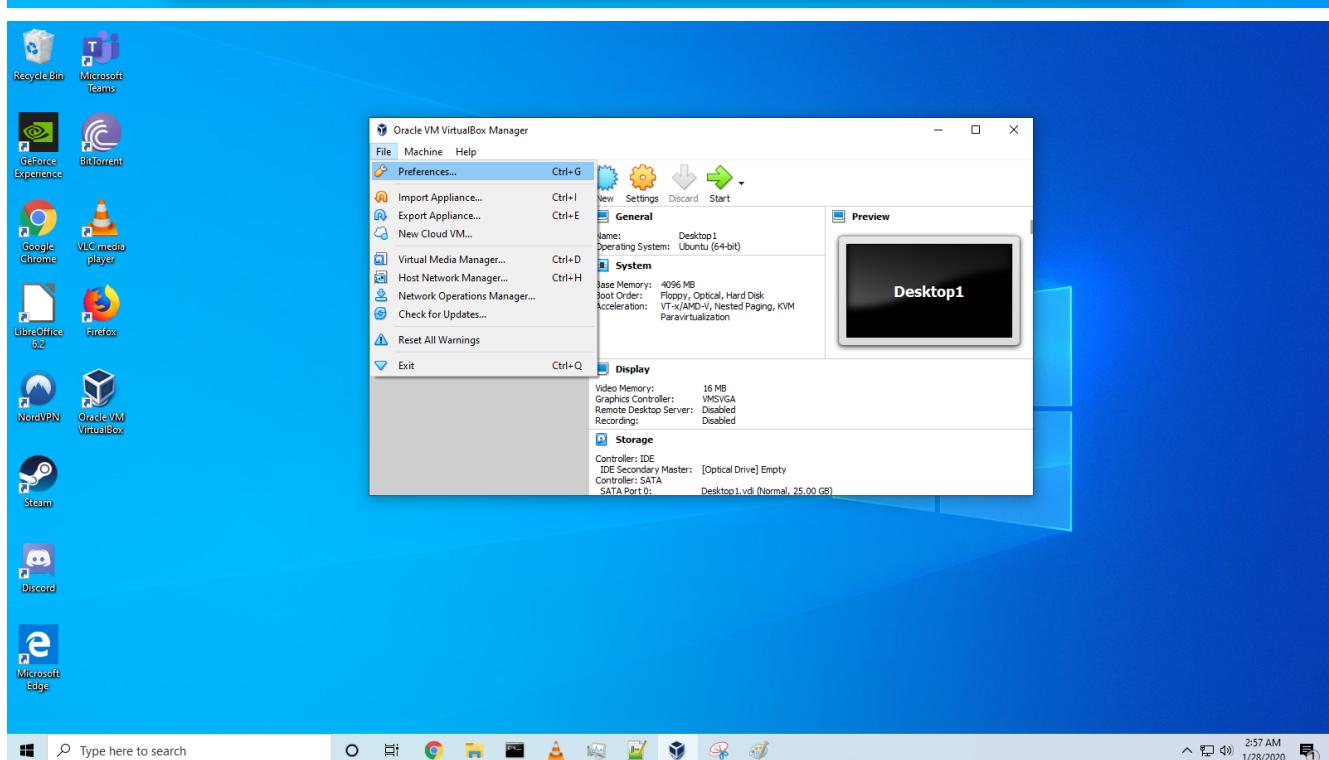
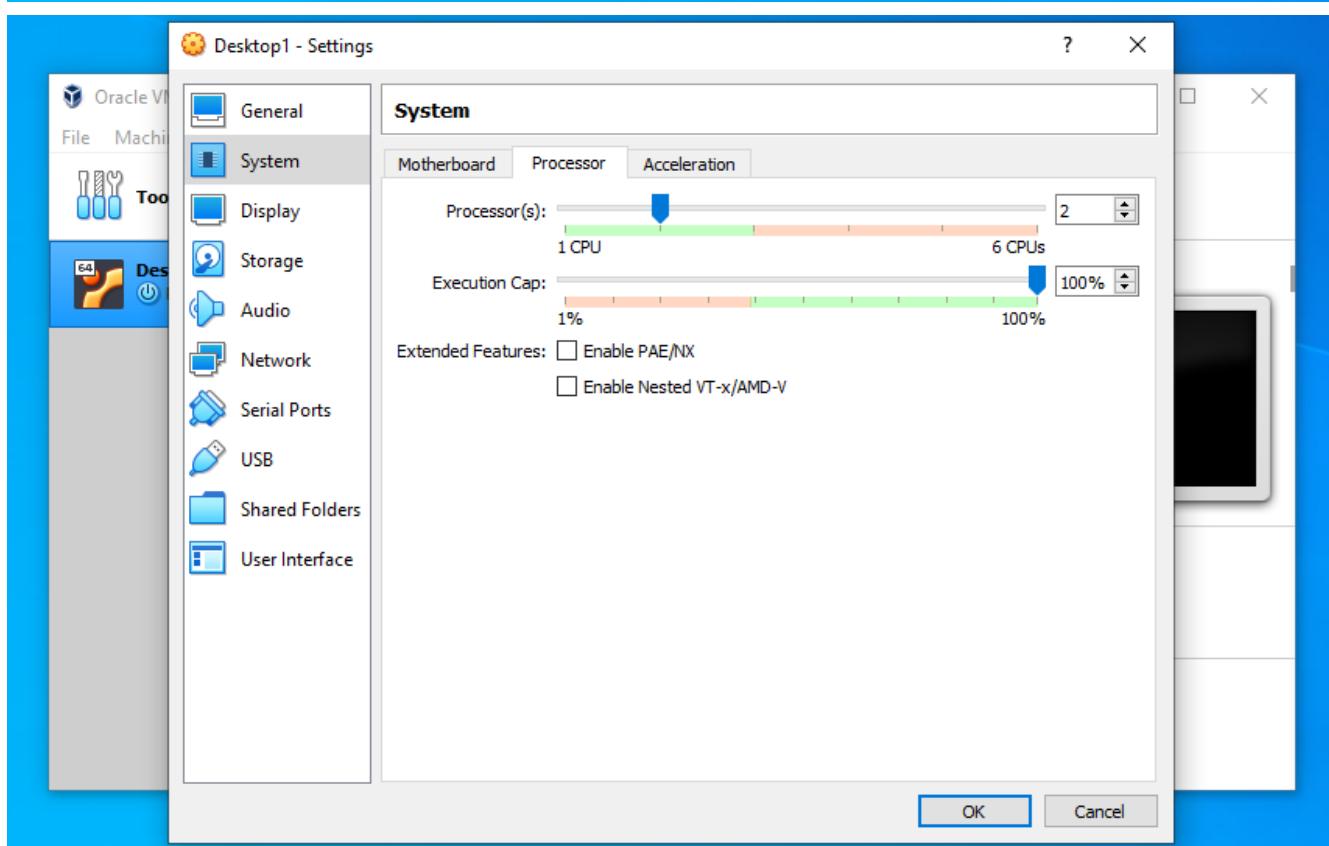
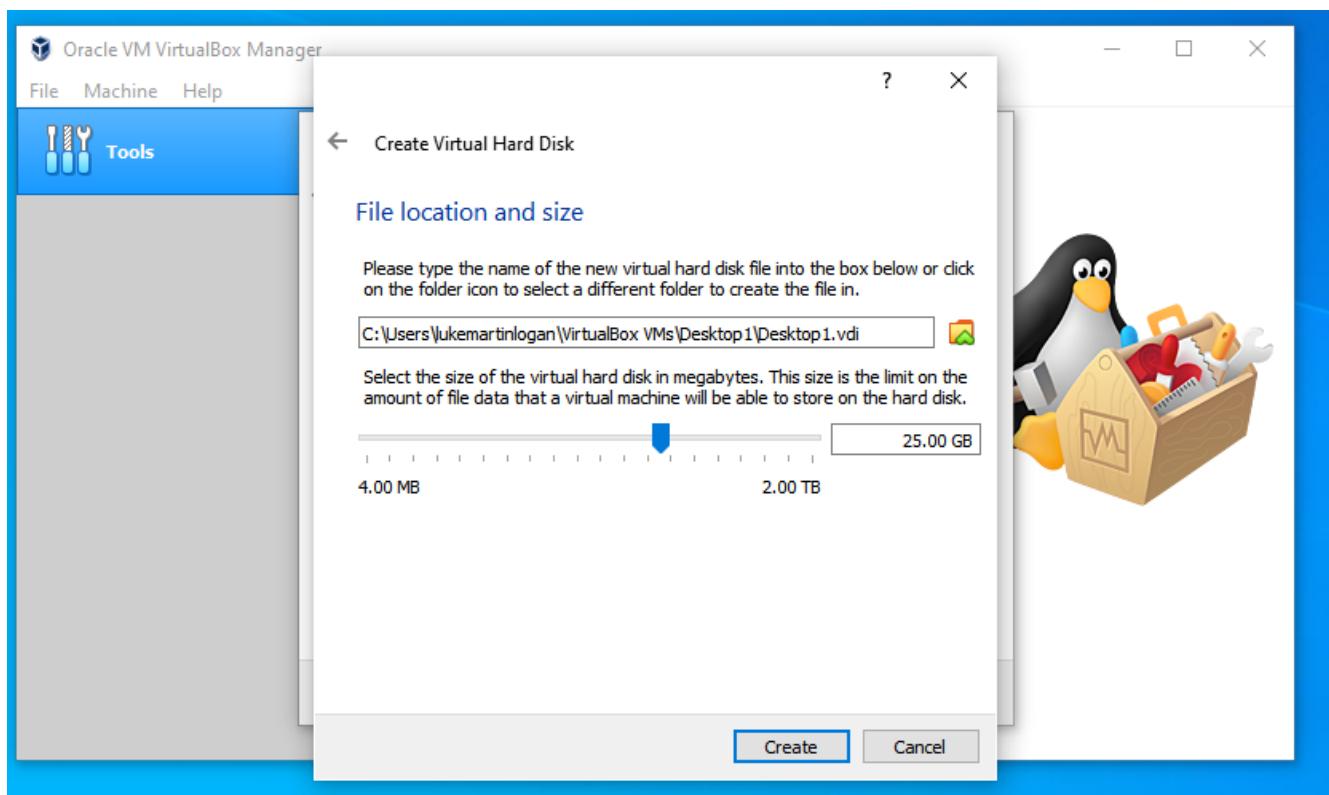
(d) Download Ubuntu

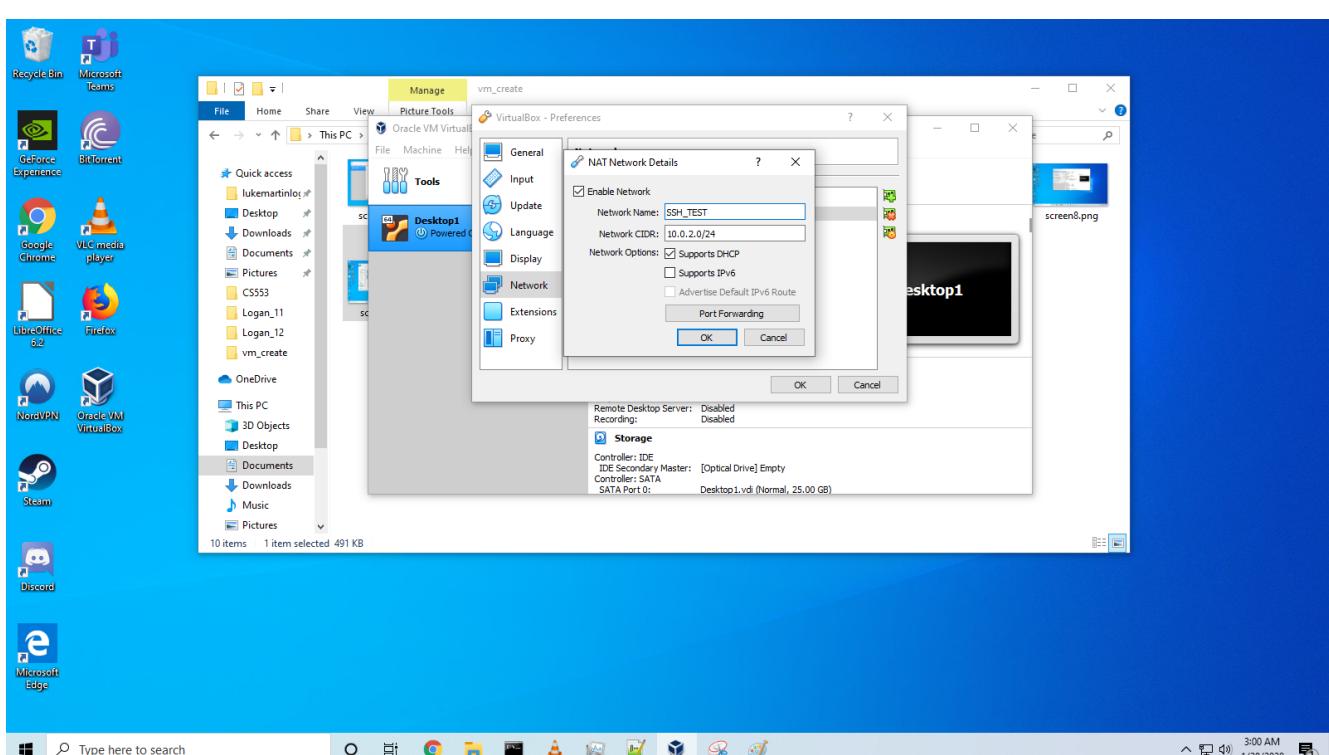
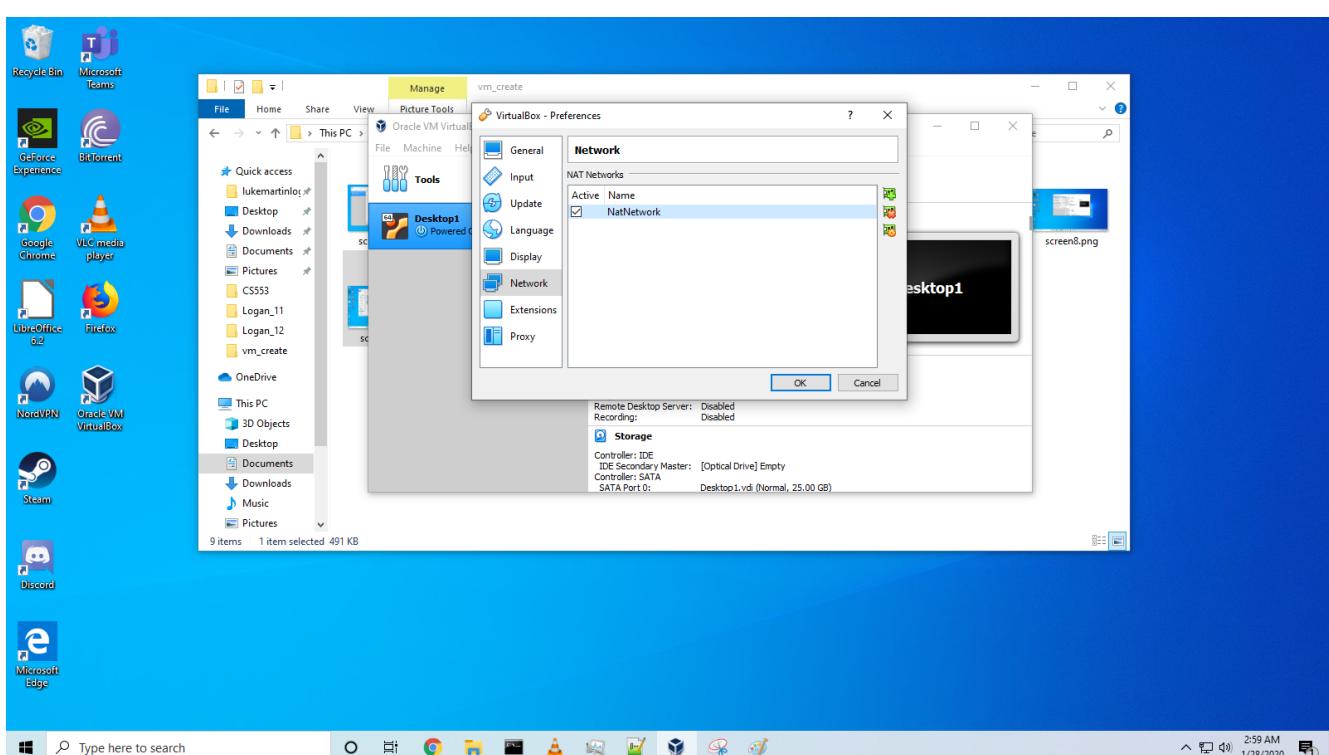
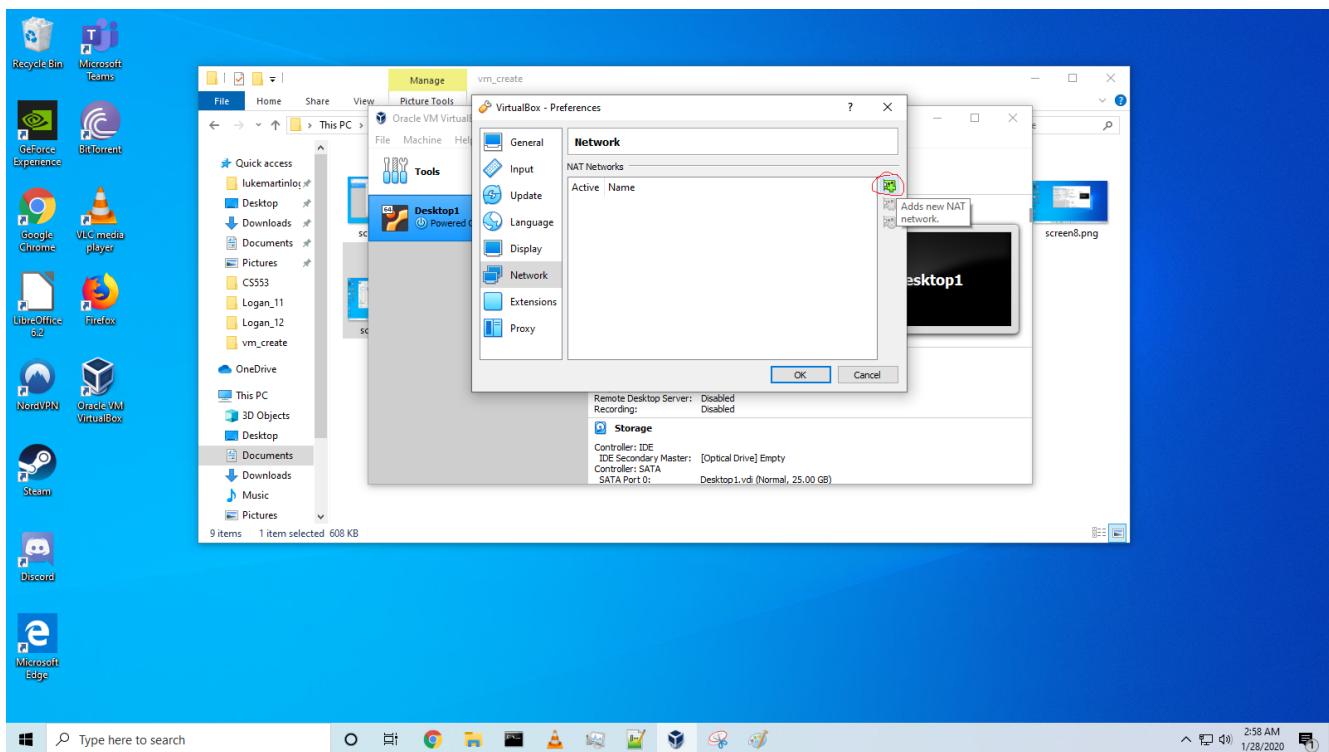


(e) Create new VM

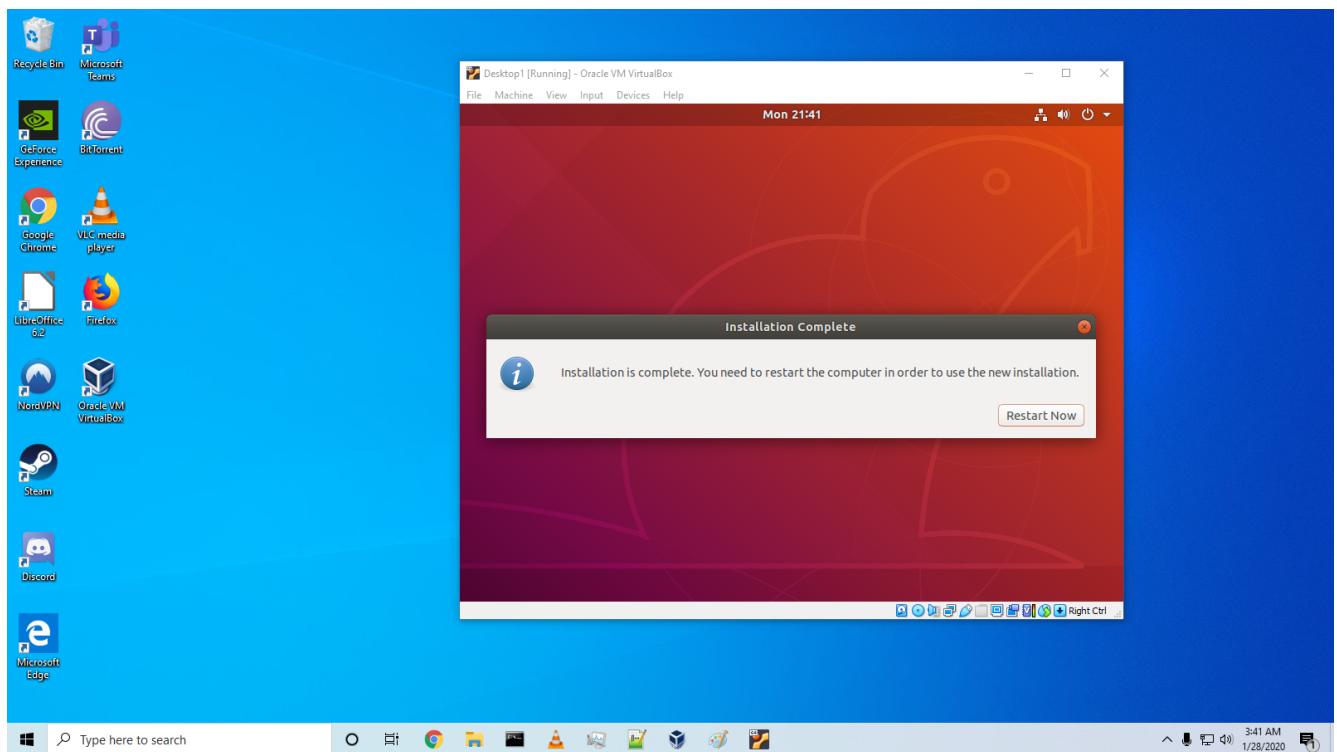




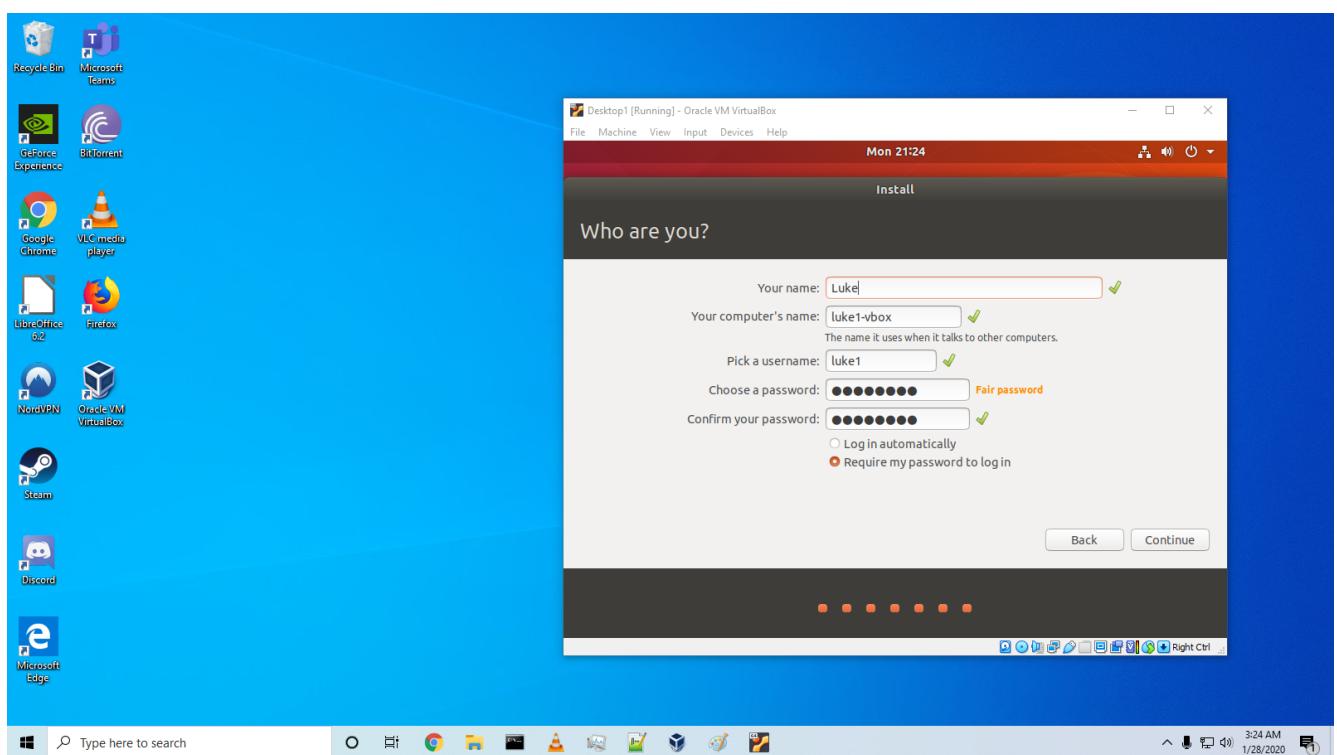




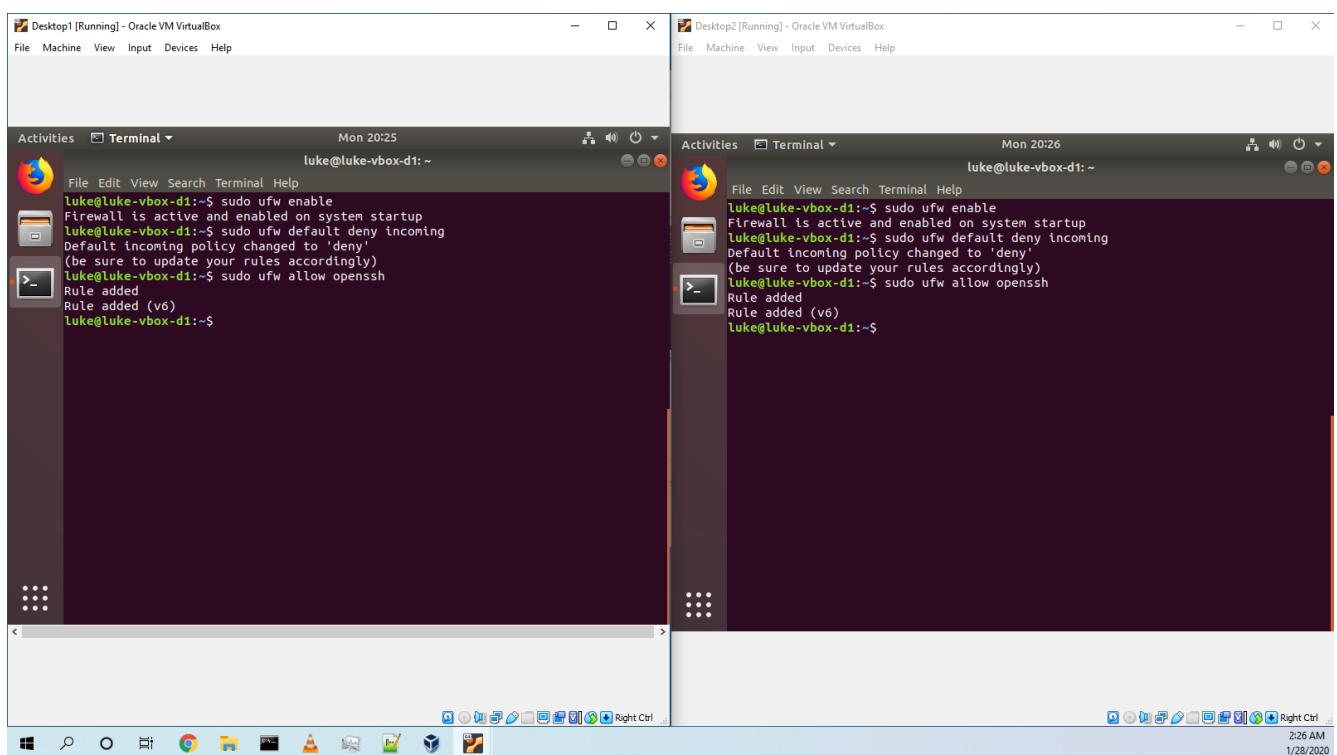
(f) Install Ubuntu



(g) Create user account



(h) Turn on firewall and block all ports



(i) Enable SSH access (shown in the previous image)

- (j) Create new VM with same specs as first one (shown in previous images with both VMs open)
- (k) Create private/public key pairs on both VMs

```

Desktop1 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Activities Terminal Mon 20:02 luke@luke-vbox-d1:~ 
File Edit View Search Terminal Help
luke@luke-vbox-d1:~$ ssh-keygen
Generating public/private rsa key pair.
Enter file in which to save the key (/home/luke/.ssh/id_rsa):
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /home/luke/.ssh/id_rsa.
Your public key has been saved in /home/luke/.ssh/id_rsa.pub.
The key fingerprint is:
SHA256:QIfH8RpQ0sFZL0ov+vkY82/aIPSJHJ3Ex+97lti3jY luke@luke-vbox-d1
The key's randomart image is:
+---[RSA 2048]---+
 .++.
 ooo+ .
 +oB+ .
 o *.* ..
 . o B S ..
 o * * o .
 . =+.
 . B+oE.
 | +o+*o.o.
 +---[SHA256]----+
luke@luke-vbox-d1:~$ 

Desktop2 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Activities Terminal Mon 20:02 luke@luke-vbox-d1:~ 
File Edit View Search Terminal Help
luke@luke-vbox-d1:~$ ssh-keygen
Generating public/private rsa key pair.
Enter file in which to save the key (/home/luke/.ssh/id_rsa):
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /home/luke/.ssh/id_rsa.
Your public key has been saved in /home/luke/.ssh/id_rsa.pub.
The key fingerprint is:
SHA256:S+qLGFuarJCGVxipjbwvnq19kAw1lb4fNfnd5Eyldw luke@luke-vbox-d1
The key's randomart image is:
+---[RSA 2048]---+
 | 0+= O .
 | . Ooo o E .
 | @ =o. o..
 | = B . . .oo|
 | + = S . . .o|
 | ... o o +|
 | .+.. . . o|
 | .o . B . .
 | ... * .+.
 | +---[SHA256]----+
luke@luke-vbox-d1:~$ 

```

(1) Connect remotely to VMs

```

Desktop1 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Activities Terminal Mon 20:00 luke@luke-vbox-d1:~ 
File Edit View Search Terminal Help
luke@luke-vbox-d1:~$ ifconfig
enp0s3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
inet 10.0.2.15 brd 255.255.255.0 broadcast 10.0.2.255
inet6 fe80::1%eth0 brd fe80::ff:fe%eth0 mtu 128 scopeid 0x20<link>
ether 08:00:27:17:03:4e txqueuelen 1000 (Ethernet)
RX packets 129 bytes 57839 (57.8 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 131 bytes 25176 (25.1 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
inet 127.0.0.1 brd 255.255.255.0 broadcast 127.0.0.1
inet6 ::1 brd :: prefixlen 128 scopeid 0x10<host>
loop txqueuelen 1000 (Local Loopback)
RX packets 139 bytes 16807 (16.8 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 139 bytes 16807 (16.8 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

luke@luke-vbox-d1:~$ 

Desktop2 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Activities Terminal Mon 20:00 luke@luke-vbox-d1:~ 
File Edit View Search Terminal Help
luke@luke-vbox-d1:~$ ifconfig
enp0s3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
inet 10.0.2.15 brd 255.255.255.0 broadcast 10.0.2.255
inet6 fe80::1%eth0 brd fe80::ff:fe%eth0 mtu 128 scopeid 0x20<link>
ether 08:00:27:14:86:48 txqueuelen 1000 (Ethernet)
RX packets 107 bytes 54577 (54.5 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 135 bytes 25695 (25.6 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
inet 127.0.0.1 brd 255.255.255.0 broadcast 127.0.0.1
inet6 ::1 brd :: prefixlen 128 scopeid 0x10<host>
loop txqueuelen 1000 (Local Loopback)
RX packets 154 bytes 13055 (13.0 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 154 bytes 13055 (13.0 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

luke@luke-vbox-d1:~$ 

```

```

Desktop1 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Activities Terminal Mon 20:05 luke@luke-vbox-d1:~ 
File Edit View Search Terminal Help
luke@luke-vbox-d1:~$ ssh luke@10.0.2.4
The authenticity of host '10.0.2.4 (10.0.2.4)' can't be established.
ECDSA key fingerprint is SHA256:wQ4EGRzuX02o+eFPpzyf/RyqAnkHP5S4AfL4xHsqZI.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added '10.0.2.4' (ECDSA) to the list of known hosts.
luke@10.0.2.4's password:
Welcome to Ubuntu 18.04.3 LTS (GNU/Linux 5.3.0-26-generic x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:    https://landscape.canonical.com
 * Support:       https://ubuntu.com/advantage

 * Canonical Livepatch is available for installation.
   - Reduce system reboots and improve kernel security. Activate at:
     https://ubuntu.com/livepatch

227 packages can be updated.
122 updates are security updates.

Your Hardware Enablement Stack (HWE) is supported until April 2023.

The programs included with the Ubuntu system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*copyright.

Ubuntu comes with ABSOLUTELY NO WARRANTY, to the extent permitted by
applicable law.

luke@luke-vbox-d1:~$ 

Desktop2 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Activities Terminal Mon 20:05 luke@luke-vbox-d1:~ 
File Edit View Search Terminal Help
luke@luke-vbox-d1:~$ ssh luke@10.0.2.15
The authenticity of host '10.0.2.15 (10.0.2.15)' can't be established.
ECDSA key fingerprint is SHA256:Q4EGRzuX02o+eFPpzyf/RyqAnkHP5S4AfL4xHsqZI.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added '10.0.2.15' (ECDSA) to the list of known hosts.
luke@10.0.2.15's password:
Welcome to Ubuntu 18.04.3 LTS (GNU/Linux 5.3.0-26-generic x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:    https://landscape.canonical.com
 * Support:       https://ubuntu.com/advantage

 * Canonical Livepatch is available for installation.
   - Reduce system reboots and improve kernel security. Activate at:
     https://ubuntu.com/livepatch

227 packages can be updated.
122 updates are security updates.

Your Hardware Enablement Stack (HWE) is supported until April 2023.
Last login: Mon Jan 27 15:16:48 2020 from 10.0.2.4
luke@luke-vbox-d1:~$ 

```

2 Question 2

1. ssh - used to securely connect a client computer to a remote computer.

The screenshot shows two separate Ubuntu desktop environments. On the left, Desktop1 (IP 10.0.2.4) has a terminal window open with the command `ssh luke@10.0.2.15`. It displays a warning about host authenticity and asks if the user wants to continue connecting (yes/no). The user types "yes". It then prompts for the password "luke@10.0.2.15's password:" and shows the welcome message for Ubuntu 18.04.3 LTS. On the right, Desktop2 (IP 10.0.2.15) also has a terminal window open with the same command. It shows the same sequence of events, including the host fingerprint warning and the password prompt. Both terminals show the same update and security information at the bottom.

2. ssh-keygen - used to generate a public/private key pair for an SSH server.

The screenshot shows two separate Ubuntu desktop environments. On the left, Desktop1 (IP 10.0.2.4) runs `ssh-keygen`, which generates a public/private RSA key pair. It asks for a file to save the key and a passphrase. The key is saved to `/home/luke/.ssh/id_rsa`. On the right, Desktop2 (IP 10.0.2.15) also runs `ssh-keygen`, generating its own key pair. Both terminals show the key fingerprint and the randomart image for each key.

3. scp - used to copy data over an SSH connection.

The screenshot shows two separate Ubuntu desktop environments. On the left, Desktop1 (IP 10.0.2.4), a file named `file_cpy.txt` is copied to the remote host `luke@10.0.2.15` using the command `scp file_cpy.txt luke@10.0.2.15:file_cpy.txt`. A red arrow points from the cursor on the Desktop1 terminal to the recipient address in the command. On the right, Desktop2 (IP 10.0.2.15), the file is received in the current directory as `file_cpy.txt`.

4. history - shows a list of the commands entered since you started the session.

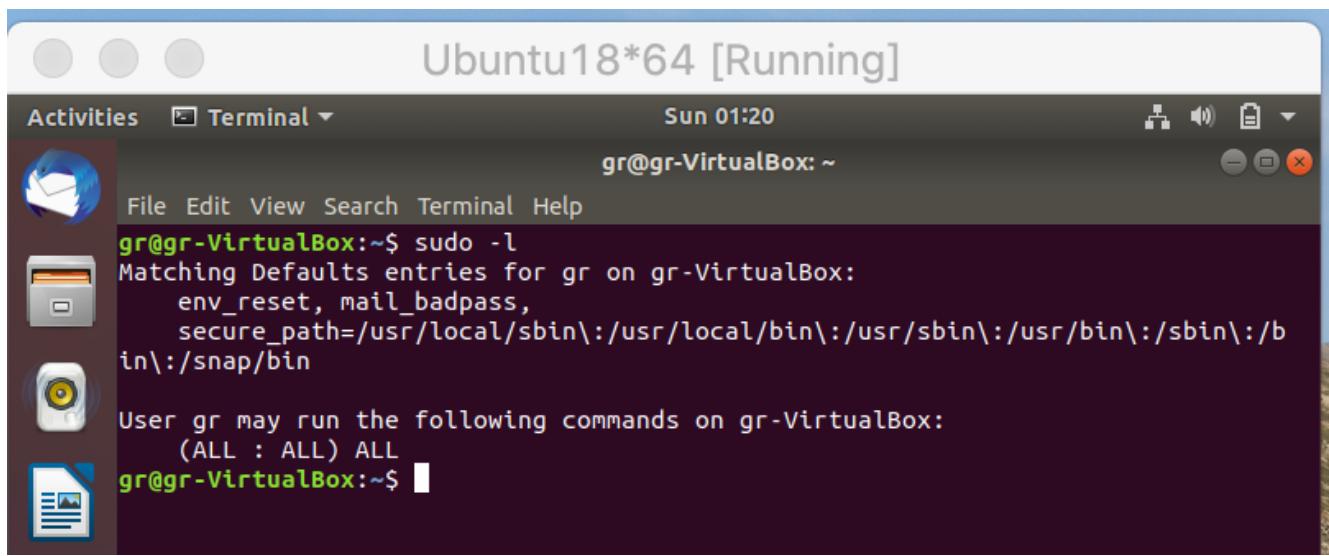
The screenshot shows a single Ubuntu desktop environment. A terminal window titled "Ubuntu18*64 [Running]" is open, showing the command `history`. The output lists the following commands:

```

gr@gr-VirtualBox:~$ history
1 sudo systemctl status ssh
2 ssh
3 man ssh
4 history
5 clear
6 history
gr@gr-VirtualBox:~$

```

5. sudo - (Super User DO) is usually used as a prefix to some command that only superuser is allowed to run. Example: Instead of reaching out to sysadmin to find-out all the root commands that user is allowed to execute, user can find it out himself using the "sudo -l"



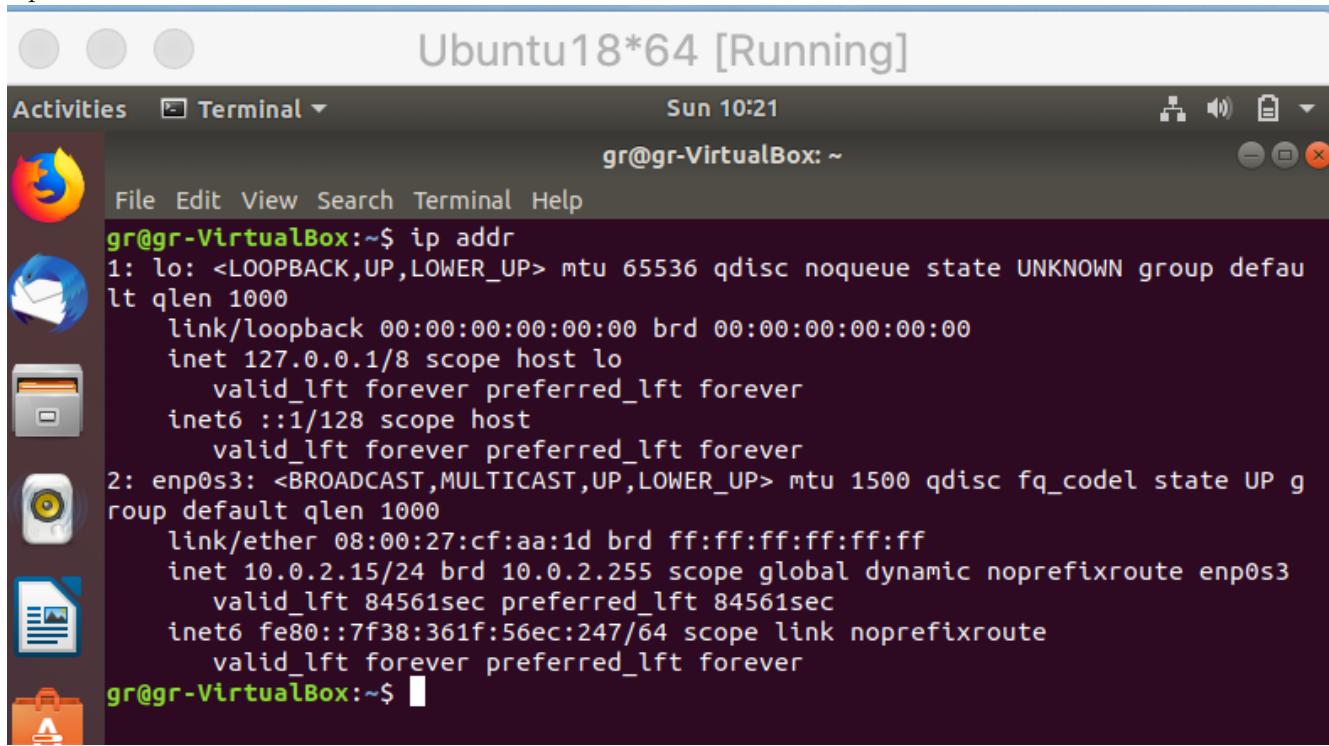
Ubuntu18*64 [Running]

Activities Terminal Sun 01:20

```
gr@gr-VirtualBox:~$ sudo -l
Matching Defaults entries for gr on gr-VirtualBox:
    env_reset, mail_badpass,
    secure_path=/usr/local/sbin\:/usr/local/bin\:/usr/sbin\:/usr/bin\:/sbin\:/bin\:/snap/bin

User gr may run the following commands on gr-VirtualBox:
    (ALL : ALL) ALL
gr@gr-VirtualBox:~$
```

6. ip - used on Linux operating systems to assign an address to a network interface and/or to configure parameters for the network interface. Example: command to list and show all ip address associated on all network interfaces "ip addr".

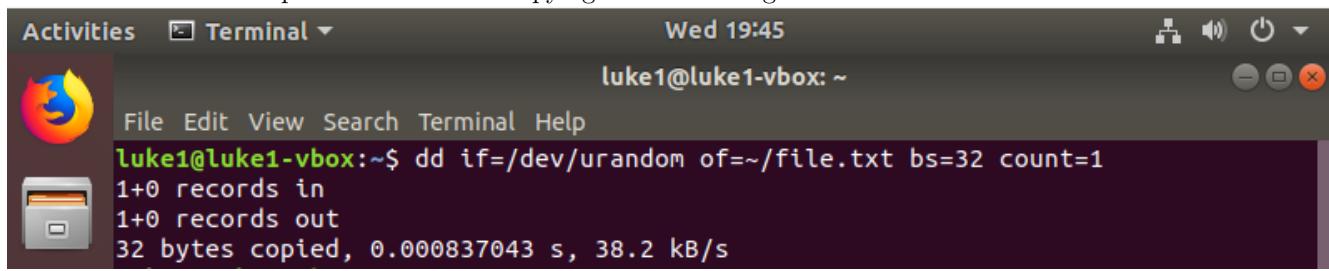


Ubuntu18*64 [Running]

Activities Terminal Sun 10:21

```
gr@gr-VirtualBox:~$ ip addr
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group default qlen 1000
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
    inet 127.0.0.1/8 scope host lo
        valid_lft forever preferred_lft forever
    inet6 ::1/128 scope host
        valid_lft forever preferred_lft forever
2: enp0s3: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel state UP group default qlen 1000
    link/ether 08:00:27:cf:aa:1d brd ff:ff:ff:ff:ff:ff
    inet 10.0.2.15/24 brd 10.0.2.255 scope global dynamic noprefixroute enp0s3
        valid_lft 84561sec preferred_lft 84561sec
    inet6 fe80::7f38:361f:56ec:247/64 scope link noprefixroute
        valid_lft forever preferred_lft forever
gr@gr-VirtualBox:~$
```

7. dd - Stands for data duplication. Used for copying and converting data.



Activities Terminal Wed 19:45

```
luke1@luke1-vbox:~$ dd if=/dev/urandom of=~/file.txt bs=32 count=1
1+0 records in
1+0 records out
32 bytes copied, 0.000837043 s, 38.2 kB/s
```

8. fdisk - is a text-based utility for viewing and managing hard disk partitions on Linux. Example: The "sudo fdisk -l" command lists the partitions on your system.

Ubuntu18*64 [Running]

Activities Terminal Sun 10:46 gr@gr-VirtualBox: ~

```
File Edit View Search Terminal Help
gr@gr-VirtualBox:~$ sudo fdisk -l
[sudo] password for gr:
Disk /dev/loop0: 160.2 MiB, 167931904 bytes, 327992 sectors
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes

Disk /dev/loop1: 149.9 MiB, 157184000 bytes, 307000 sectors
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes

Disk /dev/loop2: 54.4 MiB, 57069568 bytes, 111464 sectors
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes

Disk /dev/loop3: 88.5 MiB, 92778496 bytes, 181208 sectors
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes

Disk /dev/loop4: 4.2 MiB, 4403200 bytes, 8600 sectors
Units: sectors of 1 * 512 = 512 bytes
```

Left ☰

9. apt - (Advanced Package Tool) is a command line tool used to quickly communicate with the dpkg packaging framework and is the most effective and preferred way to manage software from the command line for Debian and Debian-based Linux distributions such as Ubuntu. Example: sudo apt-get update

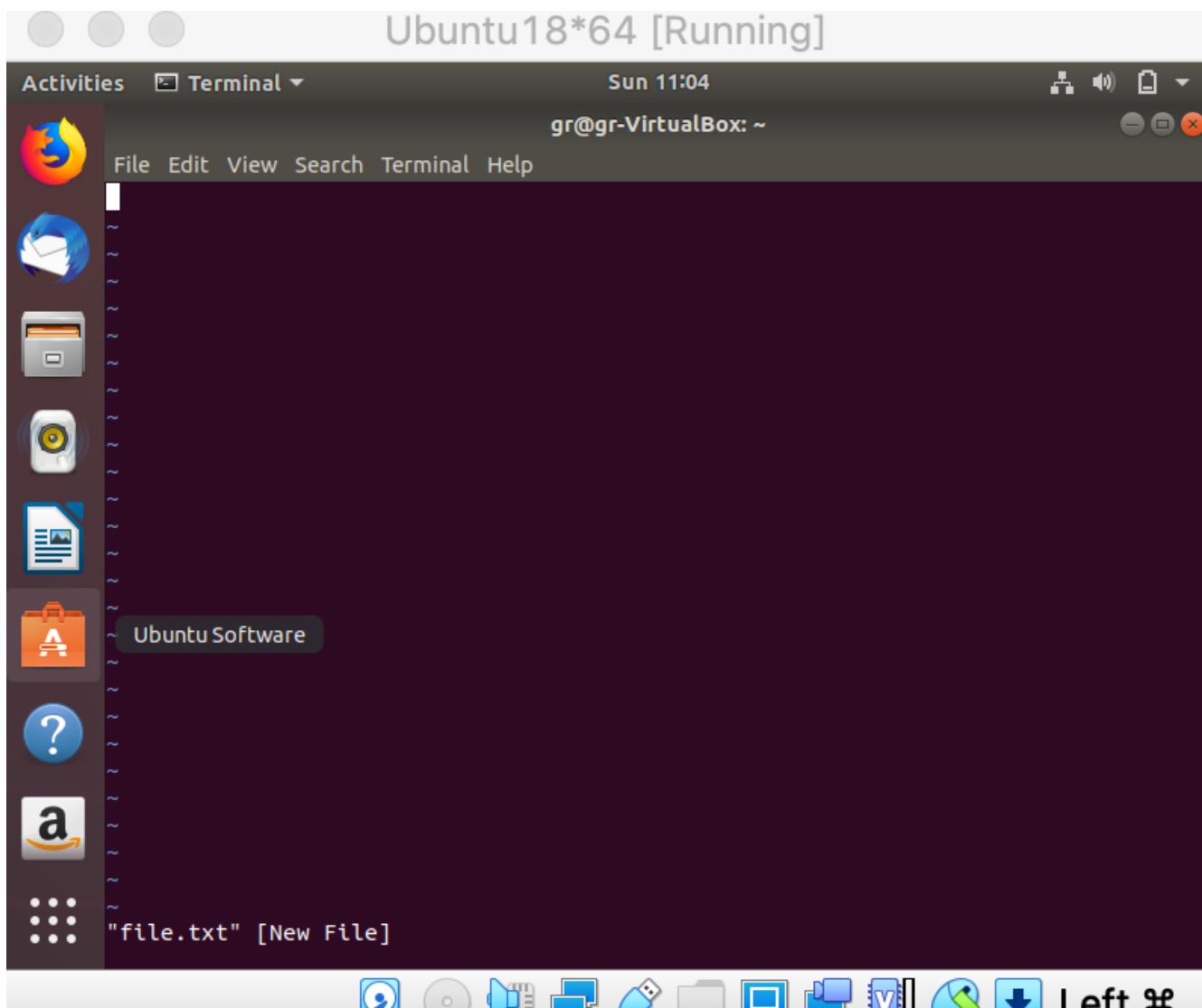
Ubuntu18*64 [Running]

Activities Terminal Sun 10:52 gr@gr-VirtualBox: ~

```
File Edit View Search Terminal Help
gr@gr-VirtualBox:~$ sudo apt-get update
Hit:1 http://us.archive.ubuntu.com/ubuntu bionic InRelease
Get:2 http://us.archive.ubuntu.com/ubuntu bionic-updates InRelease [88.7 kB]
Get:3 http://security.ubuntu.com/ubuntu bionic-security InRelease [88.7 kB]
Get:4 http://us.archive.ubuntu.com/ubuntu bionic-backports InRelease [74.6 kB]
Get:5 http://us.archive.ubuntu.com/ubuntu bionic-updates/main amd64 DEP-11 Metadata [295 kB]
Get:6 http://us.archive.ubuntu.com/ubuntu bionic-updates/main DEP-11 48x48 Icons [73.8 kB]
Get:7 http://us.archive.ubuntu.com/ubuntu bionic-updates/main DEP-11 64x64 Icons [143 kB]
Get:8 http://us.archive.ubuntu.com/ubuntu bionic-updates/universe amd64 DEP-11 Metadata [264 kB]
Get:9 http://us.archive.ubuntu.com/ubuntu bionic-updates/universe DEP-11 48x48 Icons [203 kB]
Get:10 http://us.archive.ubuntu.com/ubuntu bionic-updates/universe DEP-11 64x64 Icons [444 kB]
Get:11 http://us.archive.ubuntu.com/ubuntu bionic-updates/multiverse amd64 DEP-11 Metadata [2,464 B]
Get:12 http://us.archive.ubuntu.com/ubuntu bionic-backports/universe amd64 DEP-11 Metadata [7,960 B]
Get:13 http://security.ubuntu.com/ubuntu bionic-security/main amd64 DEP-11 Metadata [38.6 kB]
Get:14 http://security.ubuntu.com/ubuntu bionic-security/main DEP-11 48x48 Icons [17.6 kB]
Get:15 http://security.ubuntu.com/ubuntu bionic-security/main DEP-11 64x64 Icons [41.5 kB]
Get:16 http://security.ubuntu.com/ubuntu bionic-security/universe amd64 DEP-11 Metadata [42.1 kB]
```

Left ☰

10. vi - a command-line text editor. It will create a new file and write it to the specified location when you save. Example: vi file.txt



11. time - gets the execution time of a program Example: We can use the type command to determine whether time is a binary or a built-in keyword "type time"

```
lukemartinlogan@lukemartinlogan-mint-desktop2:~
```

```
File Edit View Search Terminal Help
```

```
lukemartinlogan@lukemartinlogan-mint-desktop2:~$ time bash generate-dataset.sh df10M.txt 10000000
```

```
real 0m48.453s
user 0m43.049s
sys 0m14.797s
```

12. tar - stands for tape archive, which is the most commonly used tape drive backup command used by the Linux/Unix system Example: This command will create a tar archive file example.tar for a directory /home in current working directory "tar -cvf example.tar /home"

```
Ubuntu18*64 [Running]
```

```
Activities Terminal Sun 11:34 gr@gr-VirtualBox:~
```

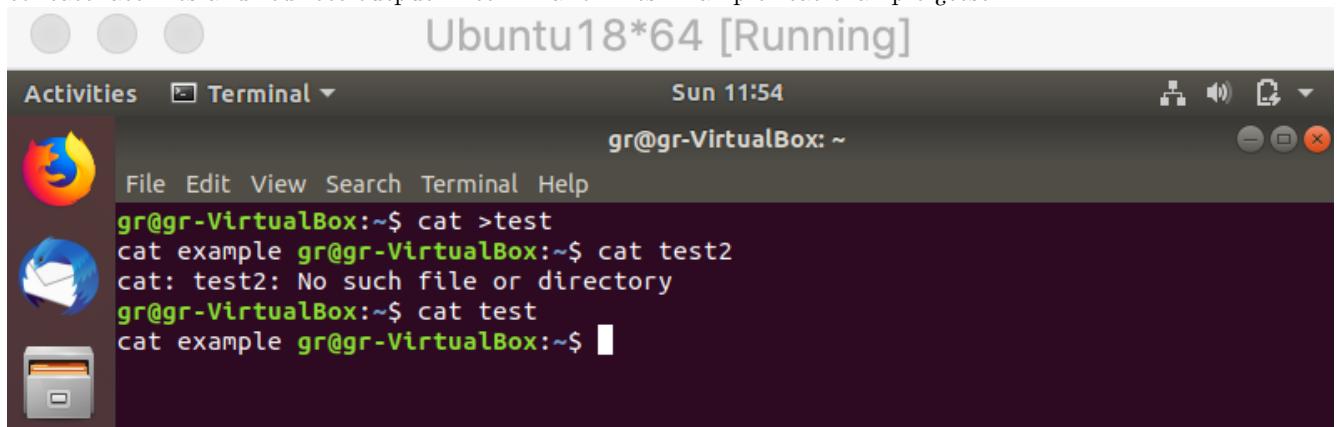
```
File Edit View Search Terminal Help
```

```
gr@gr-VirtualBox:~$ tar -cvf example.tar /home
```

```
tar: Removing leading '/' from member names
/home/
/home/gr/
/home/gr/extar/
/home/gr/.bashrc
/home/gr/.profile
/home/gr/.local/
/home/gr/.local/share/
/home/gr/.local/share/applications/
/home/gr/.local/share/app-info/
/home/gr/.local/share/app-info/xmlls/
/home/gr/.local/share/app-info/xmlls/extensions-web.xml
/home/gr/.local/share/flatpak/
/home/gr/.local/share/flatpak/db/
/home/gr/.local/share/evolution/
/home/gr/.local/share/evolution/addressbook/
/home/gr/.local/share/evolution/addressbook/system/
/home/gr/.local/share/evolution/addressbook/system/contacts.db
/home/gr/.local/share/evolution/addressbook/system/photos/
/home/gr/.local/share/evolution/addressbook/trash/
/home/gr/.local/share/evolution/memos/
/home/gr/.local/share/evolution/memos/trash/
/home/gr/.local/share/evolution/mail/
/home/gr/.local/share/evolution/mail/trash/
/home/gr/.local/share/evolution/calendar/
/home/gr/.local/share/evolution/calendar/system/
/home/gr/.local/share/evolution/calendar/system/calendar.ics
```

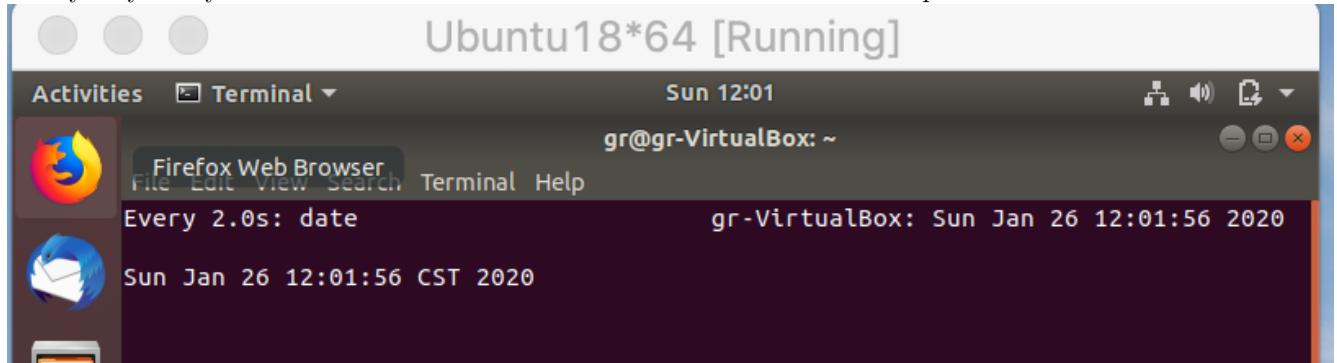
13. cat - (short for “concatenate”). cat command allows us to create single or multiple files, view contents of file,

concatenate files and redirect output in terminal or files Example: cat example >test



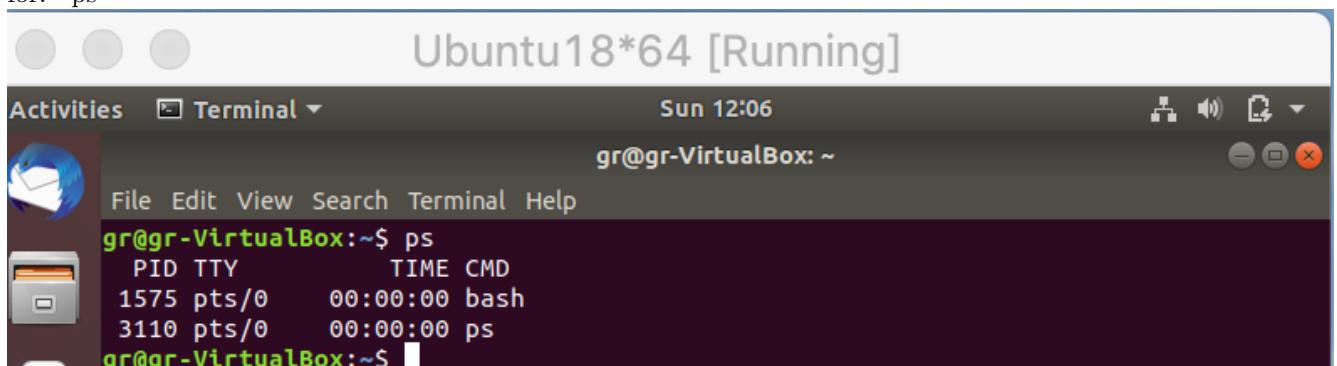
```
File Edit View Search Terminal Help
gr@gr-VirtualBox:~$ cat >test
cat example gr@gr-VirtualBox:~$ cat test2
cat: test2: No such file or directory
gr@gr-VirtualBox:~$ cat test
cat example gr@gr-VirtualBox:~$
```

14. watch - runs command repeatedly, displaying its output and errors Example: The basic usage of the watch command is very easy - all you have to do is to run the tool with a command name as input. "watch date"



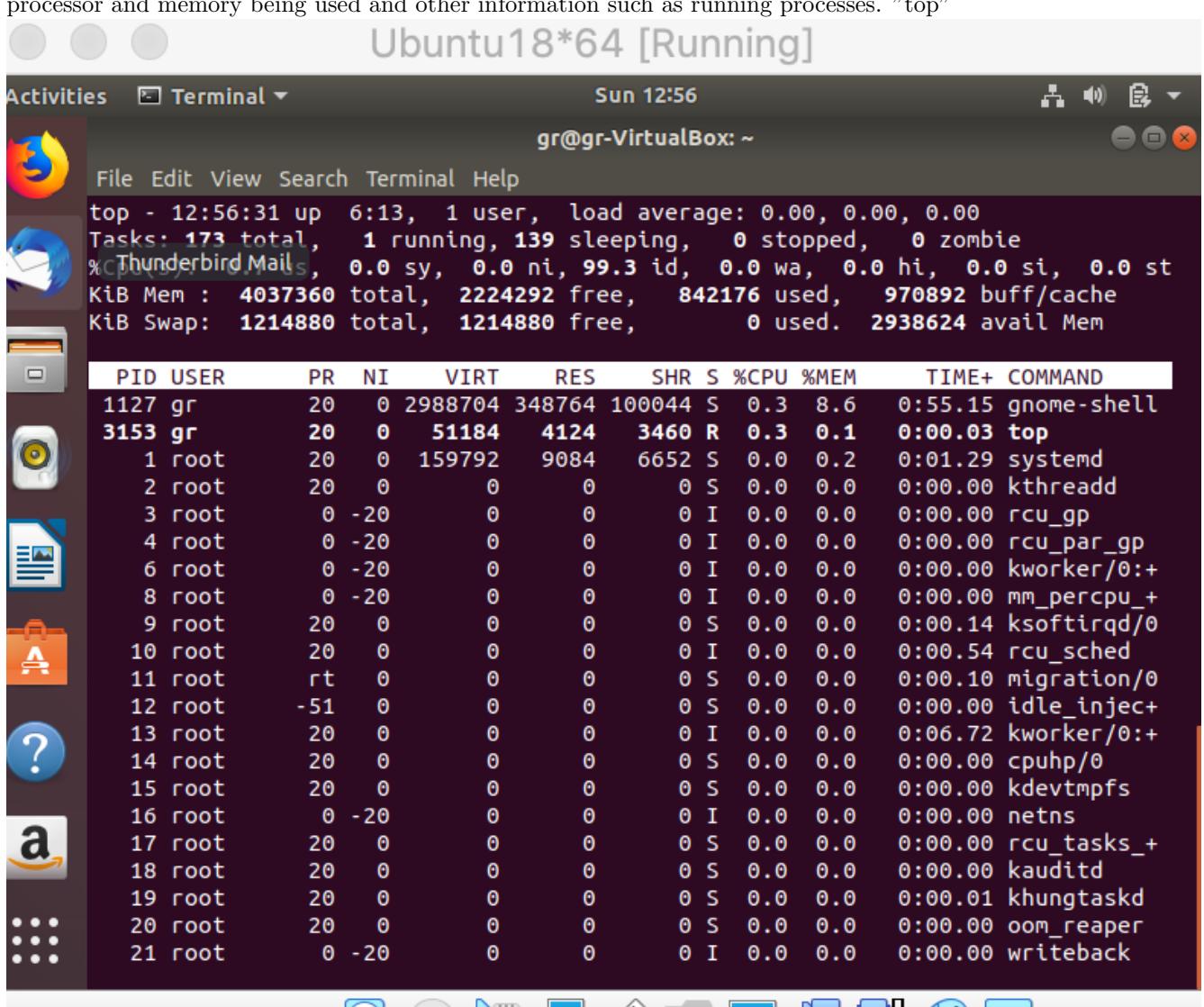
```
File Edit View Search Terminal Help
Every 2.0s: date
Sun Jan 26 12:01:56 CST 2020
gr-VirtualBox: Sun Jan 26 12:01:56 2020
```

15. ps - process status for viewing information related with the processes on a system which stands as abbreviation for. "ps"



```
File Edit View Search Terminal Help
gr@gr-VirtualBox:~$ ps
 PID TTY      TIME CMD
 1575 pts/0    00:00:00 bash
 3110 pts/0    00:00:00 ps
gr@gr-VirtualBox:~$
```

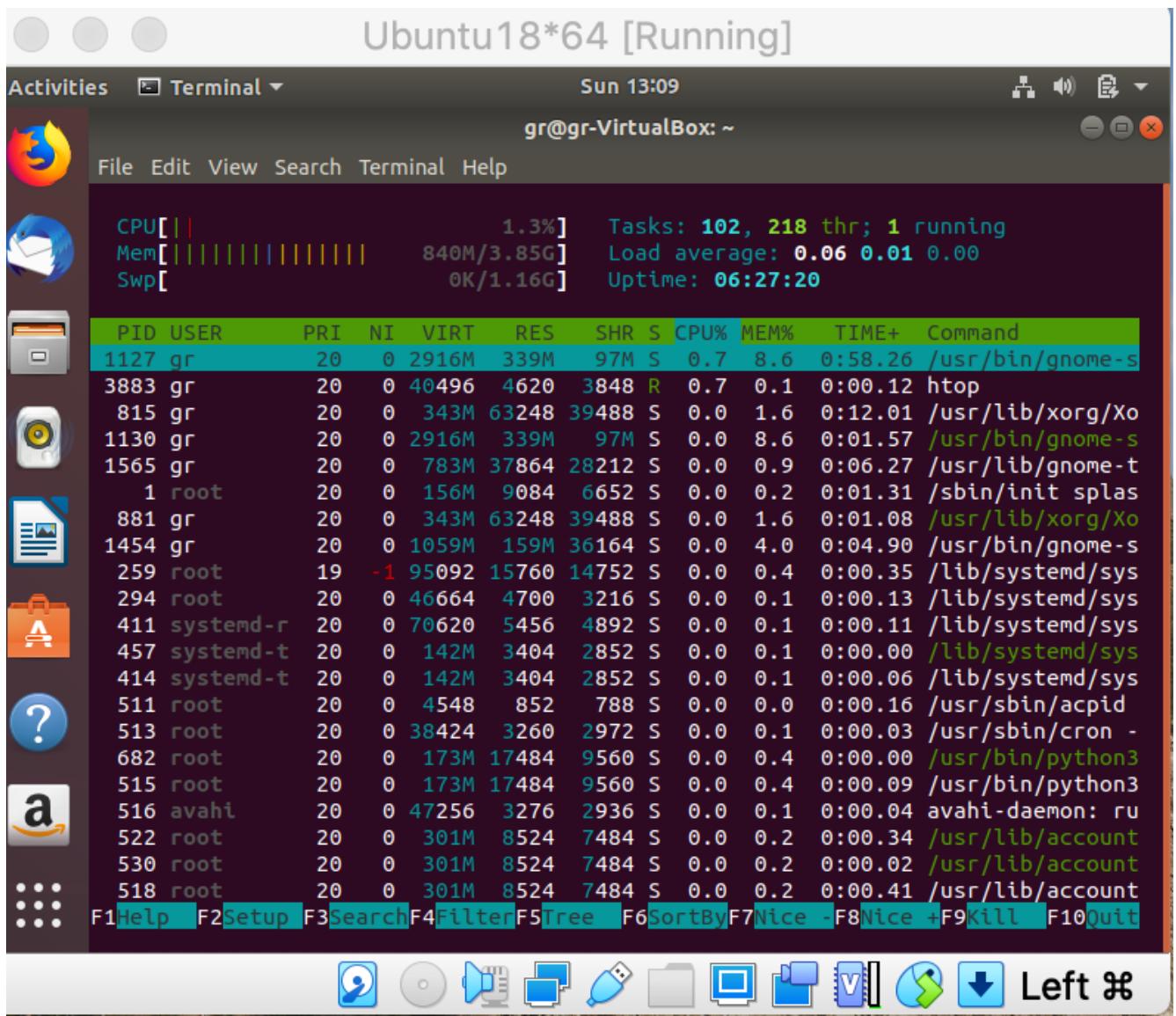
16. top - displays Linux box's processor operation, and also displays real-time kernel-managed tasks. It will display processor and memory being used and other information such as running processes. "top"



```
File Edit View Search Terminal Help
top - 12:56:31 up 6:13, 1 user, load average: 0.00, 0.00, 0.00
Tasks: 173 total, 1 running, 139 sleeping, 0 stopped, 0 zombie
%CPU(s): 0.0 sy, 0.0 ni, 99.3 id, 0.0 wa, 0.0 hi, 0.0 si, 0.0 st
KiB Mem : 4037360 total, 2224292 free, 842176 used, 970892 buff/cache
KiB Swap: 1214880 total, 1214880 free, 0 used. 2938624 avail Mem

PID USER      PR  NI    VIRT    RES    SHR S %CPU %MEM     TIME+ COMMAND
1127 gr        20   0 2988704 348764 100044 S  0.3  8.6  0:55.15 gnome-shell
3153 gr        20   0  51184  4124  3460 R  0.3  0.1  0:00.03 top
 1 root       20   0 159792  9084  6652 S  0.0  0.2  0:01.29 systemd
 2 root       20   0      0      0      0 S  0.0  0.0  0:00.00 kthreadd
 3 root       0 -20      0      0      0 I  0.0  0.0  0:00.00 rcu_gp
 4 root       0 -20      0      0      0 I  0.0  0.0  0:00.00 rcu_par_gp
 6 root       0 -20      0      0      0 I  0.0  0.0  0:00.00 kworker/0:+
 8 root       0 -20      0      0      0 I  0.0  0.0  0:00.00 mm_percpu_+
 9 root       20   0      0      0      0 S  0.0  0.0  0:00.14 ksoftirqd/0
10 root      20   0      0      0      0 I  0.0  0.0  0:00.54 rcu_sched
11 root      rt   0      0      0      0 S  0.0  0.0  0:00.10 migration/0
12 root      -51   0      0      0      0 S  0.0  0.0  0:00.00 idle_inject+
13 root      20   0      0      0      0 I  0.0  0.0  0:06.72 kworker/0:+
14 root      20   0      0      0      0 S  0.0  0.0  0:00.00 cpuhp/0
15 root      20   0      0      0      0 S  0.0  0.0  0:00.00 kdevtmpfs
16 root      0 -20      0      0      0 I  0.0  0.0  0:00.00 netns
17 root      20   0      0      0      0 S  0.0  0.0  0:00.00 rcu_tasks_+
18 root      20   0      0      0      0 S  0.0  0.0  0:00.00 kauditd
19 root      20   0      0      0      0 S  0.0  0.0  0:00.01 khungtaskd
20 root      20   0      0      0      0 S  0.0  0.0  0:00.00 oom_reaper
21 root      0 -20      0      0      0 I  0.0  0.0  0:00.00 writeback
```

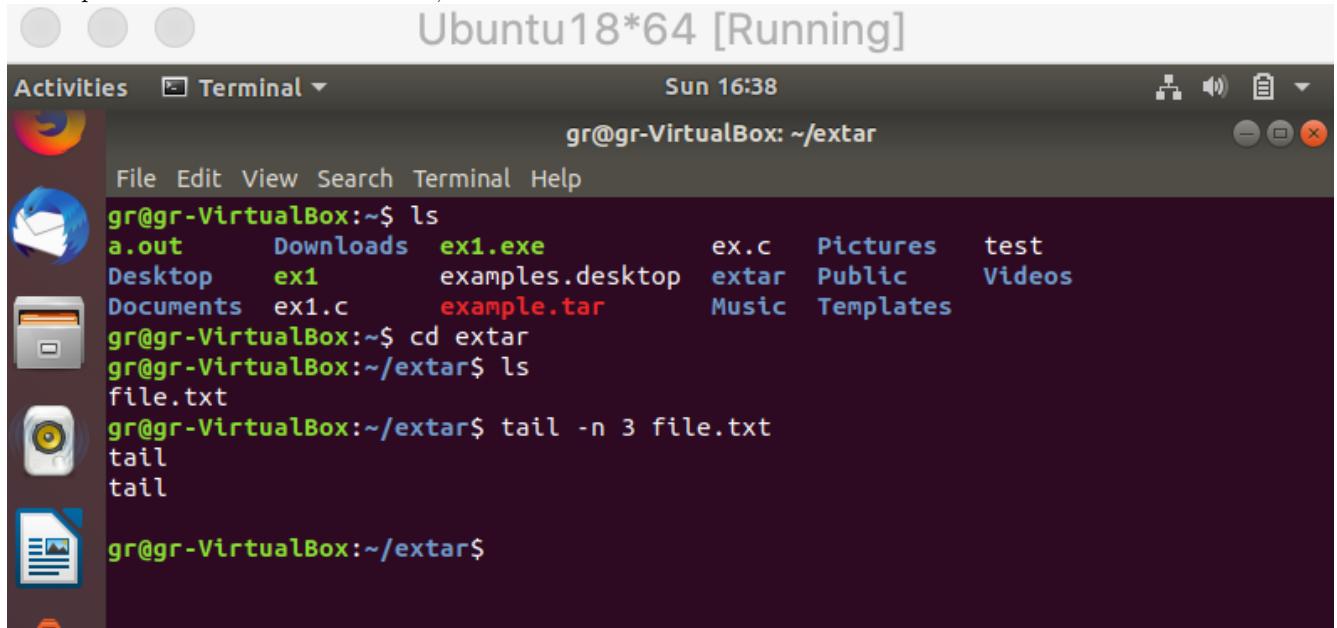
17. htop - allows to monitor processes running on the system along with all of their command lines. We can perform process-related tasks (killing, renicing) without accessing its PIDs.



18. gcc - stands for GNU Compiler Collections and is used to compile mainly C and C++ languages

```
gr@gr-VirtualBox:~$ vi ex1.c
gr@gr-VirtualBox:~$ gcc ex1.c
gr@gr-VirtualBox:~$ ls
a.out      Downloads      example.tar  Music      Templates
Desktop   ex1.c          ex.c        Pictures  test
Amazon    examples.desktop extar       Public    Videos
gr@gr-VirtualBox:~$
```

19. tail - a command which prints the last few number of lines of a certain file, then terminates. Example 1: By default “tail” prints the last 10 lines of a file, then exits.



20. grep - globally search for regular expression and print out. The grep filter searches a file for a particular character pattern, and displays all lines containing that pattern. " grep -c "tail" file.txt "

Ubuntu18*64 [Running]

Activities Terminal Sun 16:53 gr@gr-VirtualBox: ~/extar

File Edit View Search Terminal Help

```
gr@gr-VirtualBox:~$ ls
a.out      Downloads  ex1.exe          ex.c    Pictures   test
Desktop    ex1       examples.desktop  extar   Public     Videos
Documents  ex1.c    example.tar       Music   Templates
```

```
gr@gr-VirtualBox:~$ cd extar
gr@gr-VirtualBox:~/extar$ ls
file.txt
gr@gr-VirtualBox:~/extar$ grep -c "tail" file.txt
17
gr@gr-VirtualBox:~/extar$
```

21. kill - command in Linux used to manually terminate processes. Kill order sends a signal to a process stopping the cycle. kill -l :To display all the available signals

Ubuntu18*64 [Running]

Activities Terminal Sun 18:14 gr@gr-VirtualBox: ~

File Edit View Search Terminal Help

```
gr@gr-VirtualBox:~/extar$ cd ..
gr@gr-VirtualBox:~$ kill -l
 1) SIGHUP      2) SIGINT      3) SIGQUIT      4) SIGILL      5) SIGTRAP
 6) SIGABRT     7) SIGBUS      8) SIGFPE      9) SIGKILL     10) SIGUSR1
11) SIGSEGV     12) SIGUSR2     13) SIGPIPE     14) SIGALRM     15) SIGTERM
16) SIGSTKFLT   17) SIGCHLD     18) SIGCONT     19) SIGSTOP     20) SIGTSTP
21) SIGTTIN     22) SIGTTOU     23) SIGURG      24) SIGXCPU     25) SIGXFSZ
26) SIGVTALRM   27) SIGPROF     28) SIGWINCH    29) SIGIO       30) SIGPWR
31) SIGSYS      34) SIGRTMIN    35) SIGRTMIN+1  36) SIGRTMIN+2  37) SIGRTMIN+3
38) SIGRTMIN+4  39) SIGRTMIN+5  40) SIGRTMIN+6  41) SIGRTMIN+7  42) SIGRTMIN+8
43) SIGRTMIN+9  44) SIGRTMIN+10 45) SIGRTMIN+11 46) SIGRTMIN+12 47) SIGRTMIN+13
48) SIGRTMIN+14 49) SIGRTMIN+15 50) SIGRTMAX-14 51) SIGRTMAX-13 52) SIGRTMAX-12
53) SIGRTMAX-11 54) SIGRTMAX-10 55) SIGRTMAX-9  56) SIGRTMAX-8  57) SIGRTMAX-7
58) SIGRTMAX-6  59) SIGRTMAX-5  60) SIGRTMAX-4  61) SIGRTMAX-3  62) SIGRTMAX-2
63) SIGRTMAX-1  64) SIGRTMAX
```

22. killall - kill processes by name. killall sends a signal to all processes running any of the specified commands. If no signal name is specified, SIGTERM is sent.

Ubuntu18*64 [Running]

Activities Terminal Sun 18:26 gr@gr-VirtualBox: ~

File Edit View Search Terminal Help

```
gr@gr-VirtualBox:~$ killall -l
HUP INT QUIT ILL TRAP ABRT BUS FPE KILL USR1 SEGV USR2 PIPE ALRM TERM STKFLT
CHLD CONT STOP TSTP TTIN TTOU URG XCPU XFSZ VTALRM PROF WINCH POLL PWR SYS
gr@gr-VirtualBox:~$
```

23. du - (short for disk usage) is used to estimate the use of file space.

Ubuntu18*64 [Running]

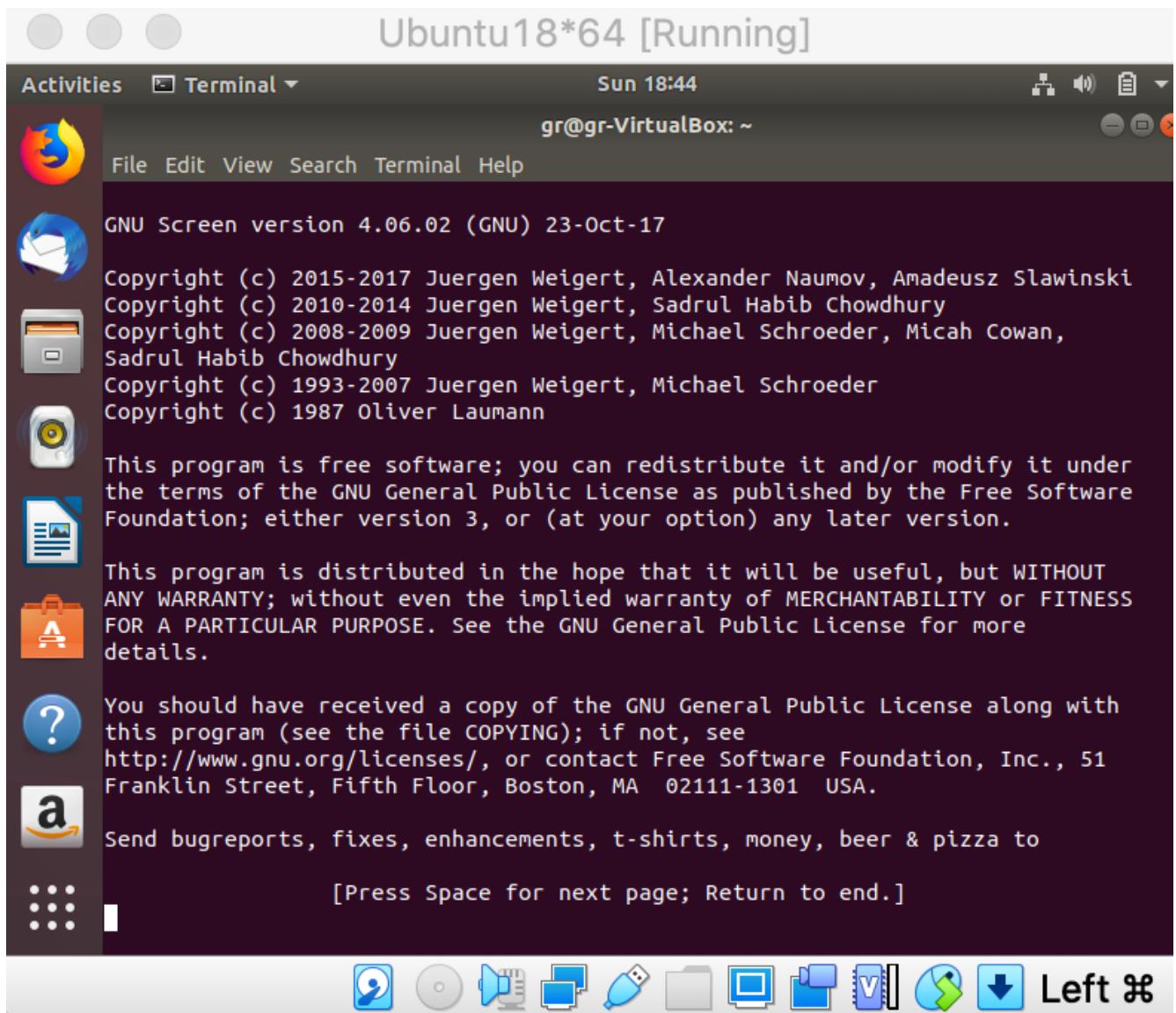
```
gr@gr-VirtualBox:~$ du
8      ./extar
4      ./local/share/applications
1128   ./local/share/app-info/xmls
1132   ./local/share/app-info
4      ./local/share/flatpak/db
8      ./local/share/flatpak
4      ./local/share/evolution/addressbook/system/photos
92     ./local/share/evolution/addressbook/system
4      ./local/share/evolution/addressbook/trash
100    ./local/share/evolution/addressbook
4      ./local/share/evolution/memos/trash
8      ./local/share/evolution/memos
4      ./local/share/evolution/mail/trash
8      ./local/share/evolution/mail
8      ./local/share/evolution/calendar/system
4      ./local/share/evolution/calendar/trash
16     ./local/share/evolution/calendar
4      ./local/share/evolution/tasks/trash
8      ./local/share/evolution/tasks
144    ./local/share/evolution
4      ./local/share/gnome-settings-daemon
4      ./local/share/ibus-table
4      ./local/share/sounds
116    ./local/share/xorg
4      ./local/share/icc
8      ./local/share/gnome-shell
12    ./local/share/keyrings
```

24. df - The df command can be used to show the free space on a Unix or Linux computer.

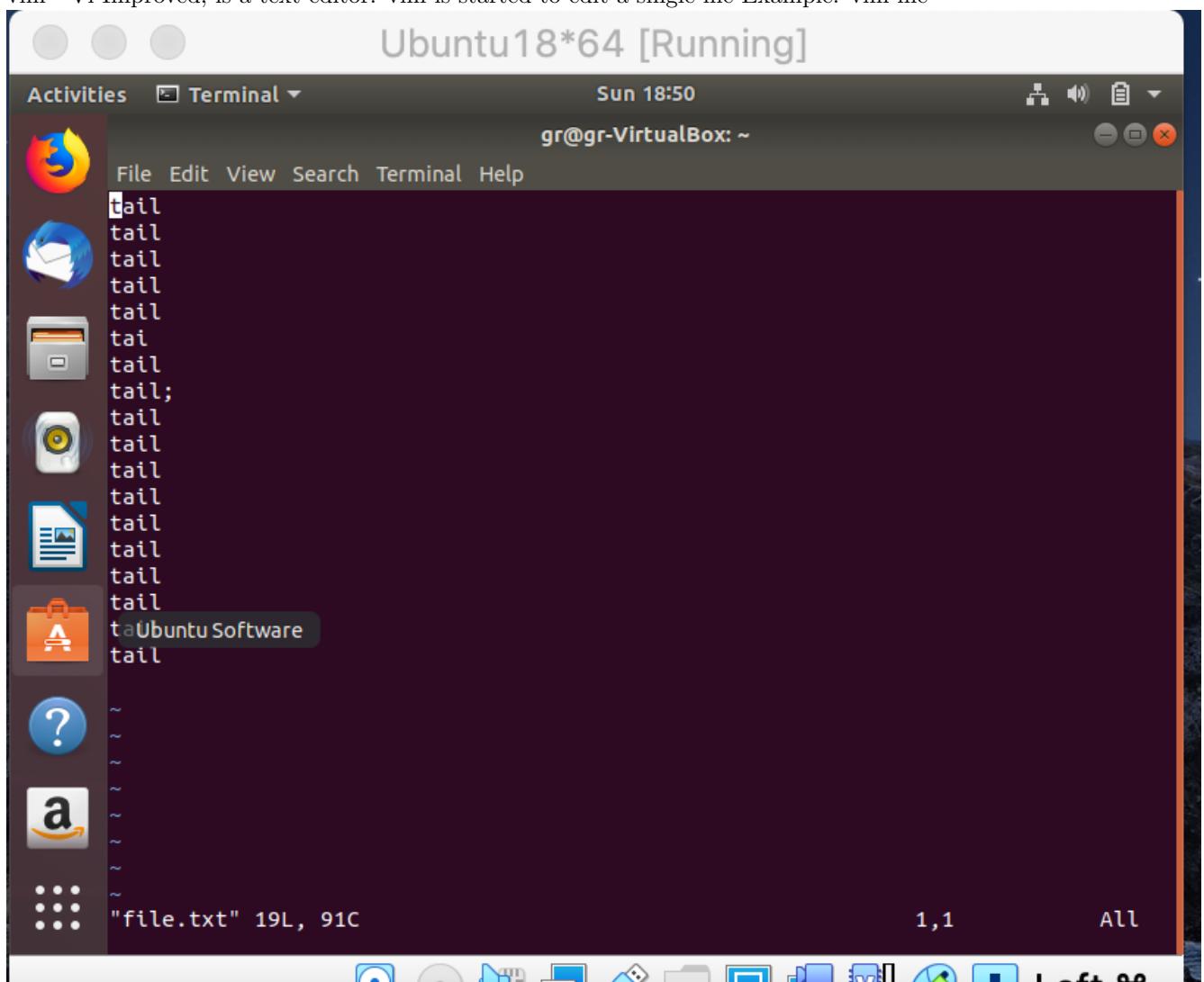
Ubuntu18*64 [Running]

```
gr@gr-VirtualBox:~$ df
Filesystem      1K-blocks    Used Available Use% Mounted on
udev            1994808      0  1994808  0% /dev
tmpfs           403736    1348  402388  1% /run
/dev/sda1       25669860  6562712  17780148 27% /
tmpfs           2018680      0  2018680  0% /dev/shm
tmpfs            5120        4    5116  1% /run/lock
tmpfs           2018680      0  2018680  0% /sys/fs/cgroup
/dev/loop2        55808    55808      0 100% /snap/core18/1066
/dev/loop3        1024    1024      0 100% /snap/gnome-logs/81
/dev/loop0       153600   153600      0 100% /snap/gnome-3-28-1804/67
/dev/loop1        1024    1024      0 100% /snap/gnome-logs/61
/dev/loop4        4352    4352      0 100% /snap/gnome-calculator/544
/dev/loop5       90624   90624      0 100% /snap/core/7270
/dev/loop6        3840    3840      0 100% /snap/gnome-system-monitor/127
/dev/loop7       15104   15104      0 100% /snap/gnome-characters/399
/dev/loop8        3840    3840      0 100% /snap/gnome-system-monitor/100
/dev/loop9       164096  164096      0 100% /snap/gnome-3-28-1804/116
/dev/loop11      91264   91264      0 100% /snap/core/8268
/dev/loop10      56064   56064      0 100% /snap/core18/1650
/dev/loop12      15104   15104      0 100% /snap/gnome-characters/296
/dev/loop13      43904   43904      0 100% /snap/gtk-common-themes/1313
/dev/loop14      46080   46080      0 100% /snap/gtk-common-themes/1440
/dev/loop15      4224    4224      0 100% /snap/gnome-calculator/406
tmpfs           403736      36  403700  1% /run/user/1000
```

25. screen -Screen command in Linux allows multiple shell sessions to be started and used from a single ssh session



26. vim - Vi Improved, is a text editor. vim is started to edit a single file Example: vim file



27. chmod - used to define or change permissions or modes on files and to restrict access only to those that are permitted. example: chmod u=r,og=r ex1.c

Ubuntu18*64 [Running]

Activities Terminal Sun 19:10 gr@gr-VirtualBox: ~

```
File Edit View Search Terminal Help
gr@gr-VirtualBox:~/extar$ cd ..
gr@gr-VirtualBox:~$ ls
a.out    Downloads  ex1.exe      ex.c   Pictures  test
Desktop  ex1       examples.desktop extar  Public    Videos
Documents ex1.c     example.tar    Music   Templates
gr@gr-VirtualBox:~$ ls -l ex1.c
-rw-r--r-- 1 gr gr 67 Jan 26 13:30 ex1.c
gr@gr-VirtualBox:~$ chmod u=r,og=r ex1.c
gr@gr-VirtualBox:~$ ls -l ex1.c
-r--r--r-- 1 gr gr 67 Jan 26 13:30 ex1.c
gr@gr-VirtualBox:~$
```

28. chown - Allows to change the user and/or group ownership of a given file, directory. Example: chown gdm ex1.c

Ubuntu18*64 [Running]

Activities Terminal Sun 19:20 gr@gr-VirtualBox: ~

```
File Edit View Search Terminal Help
/nologin
usbmux:x:107:46:usbmux daemon,,,:/var/lib/usbmux:/usr/sbin/nologin
dnsmasq:x:108:65534:dnsmasq,,,:/var/lib/misc:/usr/sbin/nologin
rtkit:x:109:114:RealtimeKit,,,:/proc:/usr/sbin/nologin
cups-pk-helper:x:110:116:user for cups-pk-helper service,,,:/home/cups-pk-helper:/usr/sbin/nologin
speech-dispatcher:x:111:29:Speech Dispatcher,,,:/var/run/speech-dispatcher:/bin/false
whoopsie:x:112:117::/nonexistent:/bin/false
kernoops:x:113:65534:Kernel Oops Tracking Daemon,,,:::/usr/sbin/nologin
saned:x:114:119::/var/lib/saned:/usr/sbin/nologin
pulse:x:115:120:PulseAudio daemon,,,:/var/run/pulse:/usr/sbin/nologin
avahi:x:116:122:Avahi mDNS daemon,,,:/var/run/avahi-daemon:/usr/sbin/nologin
colord:x:117:123:colord colour management daemon,,,:/var/lib/colord:/usr/sbin/nologin
hplip:x:118:7:HPLIP system user,,,:/var/run/hplip:/bin/false
geoclue:x:119:124::/var/lib/geoclue:/usr/sbin/nologin
gnome-initial-setup:x:120:65534::/run/gnome-initial-setup:/bin/false
gdmHelp 121:125:Gnome Display Manager:/var/lib/gdm3:/bin/false
gr:x:1000:1000:GR,,,:/home/gr:/bin/bash
sshd:x:122:65534::/run/sshd:/usr/sbin/nologin
gr@gr-VirtualBox:~$ ls -l ex1.c
-r--r--r-- 1 gr gr 67 Jan 26 13:30 ex1.c
gr@gr-VirtualBox:~$ chown grd ex1.c
chown: invalid user: 'grd'
gr@gr-VirtualBox:~$ chown gdm ex1.c
chown: changing ownership of 'ex1.c': Operation not permitted
gr@gr-VirtualBox:~$
```

29. useradd - used for adding/creating user accounts in Linux Example: sudo useradd gr2

Ubuntu18*64 [Running]

Activities Terminal Sun 19:45 gr@gr-VirtualBox: ~

```
File Edit View Search Terminal Help
gr@gr-VirtualBox:~$ sudo useradd gr2
[sudo] password for gr:
gr@gr-VirtualBox:~$
```

30. man - used to display the user manual of any command that we can run on the terminal Example: man useradd

Ubuntu18*64 [Running]

Activities Terminal Sun 19:48 gr@gr-VirtualBox: ~

```
USERADD(8) System Management Commands USERADD(8)

NAME
    useradd - create a new user or update default new user information

SYNOPSIS
    useradd [options] LOGIN

    useradd -D

    useradd -D [options]

DESCRIPTION
    LibreOffice Writer
    useradd is a low level utility for adding users. On Debian,
    administrators should usually use adduser(8) instead.

    When invoked without the -D option, the useradd command creates a new
    user account using the values specified on the command line plus the
    default values from the system. Depending on command line options, the
    useradd command will update system files and may also create the new
    user's home directory and copy initial files.

    By default, a group will also be created for the new user (see -g, -N,
    -U, and USERGROUPS_ENAB).

OPTIONS
    The options which apply to the useradd command are:
    Manual page useradd(8) line 1 (press h for help or q to quit)
```

Left

31. locate - used to find files by their filename example; locate extar

Ubuntu18*64 [Running]

Activities Terminal Sun 20:54 gr@gr-VirtualBox: ~

```
File Edit View Search Terminal Help
gr@gr-VirtualBox:~$ locate extar
/home/gr/extar
/home/gr/extar/file.txt
gr@gr-VirtualBox:~$
```

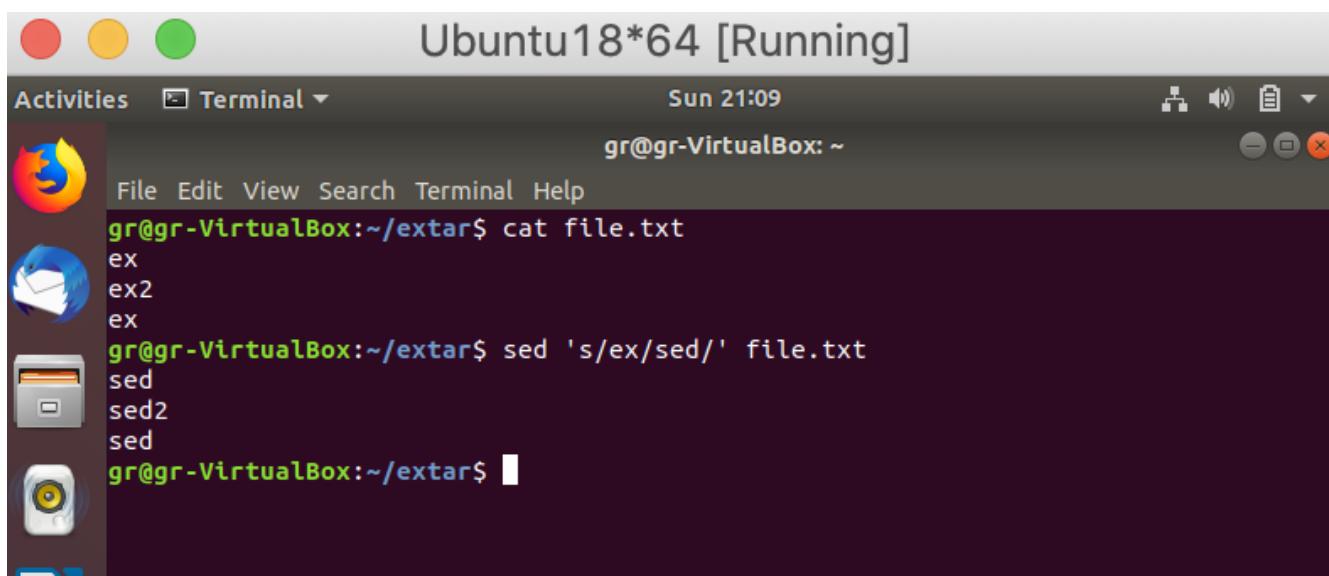
32. find - used to search and locate the list of files and directories based on conditions you specify for files that match the arguments Example: find . -name file.txt

Ubuntu18*64 [Running]

Activities Terminal Sun 20:59 gr@gr-VirtualBox: ~

```
File Edit View Search Terminal Help
gr@gr-VirtualBox:~$ find . -name file.txt
./extar/file.txt
gr@gr-VirtualBox:~$
```

33. sed - stream editor ,used for searching, find and replace, insertion or deletion Example: sed 's/ex/sed/' file.txt

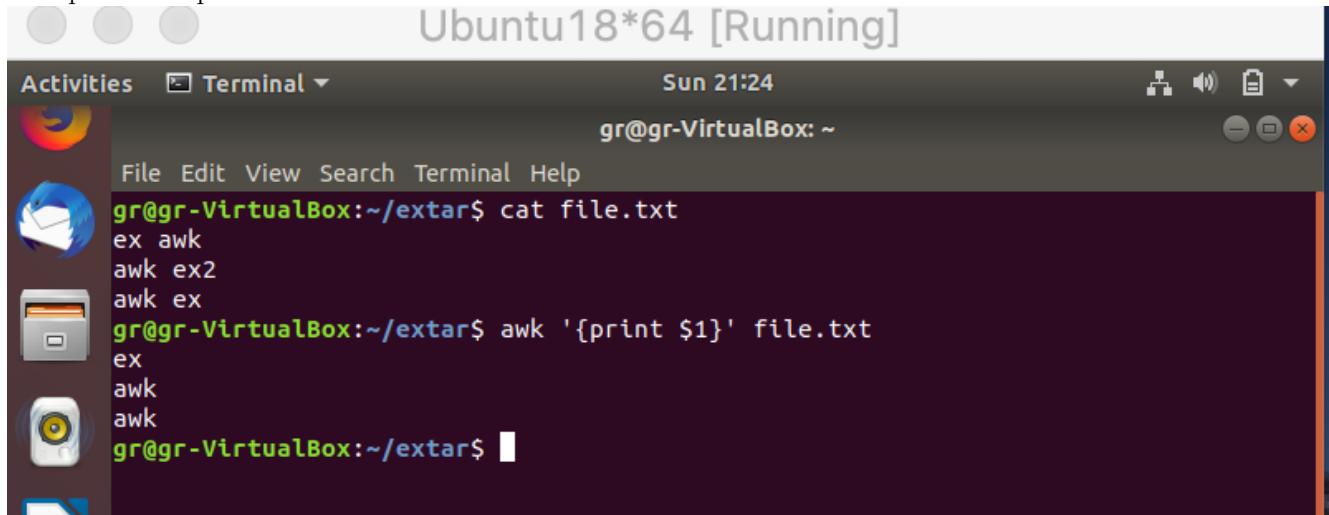


Ubuntu18*64 [Running]

Activities Terminal Sun 21:09 gr@gr-VirtualBox: ~

```
File Edit View Search Terminal Help
gr@gr-VirtualBox:~/extar$ cat file.txt
ex
ex2
ex
gr@gr-VirtualBox:~/extar$ sed 's/ex/sed/' file.txt
sed
sed2
sed
gr@gr-VirtualBox:~/extar$
```

34. awk - processes log files that contain maybe millions of lines to output a readable report that you can benefit from. example: "awk 'print 1' file.txt "

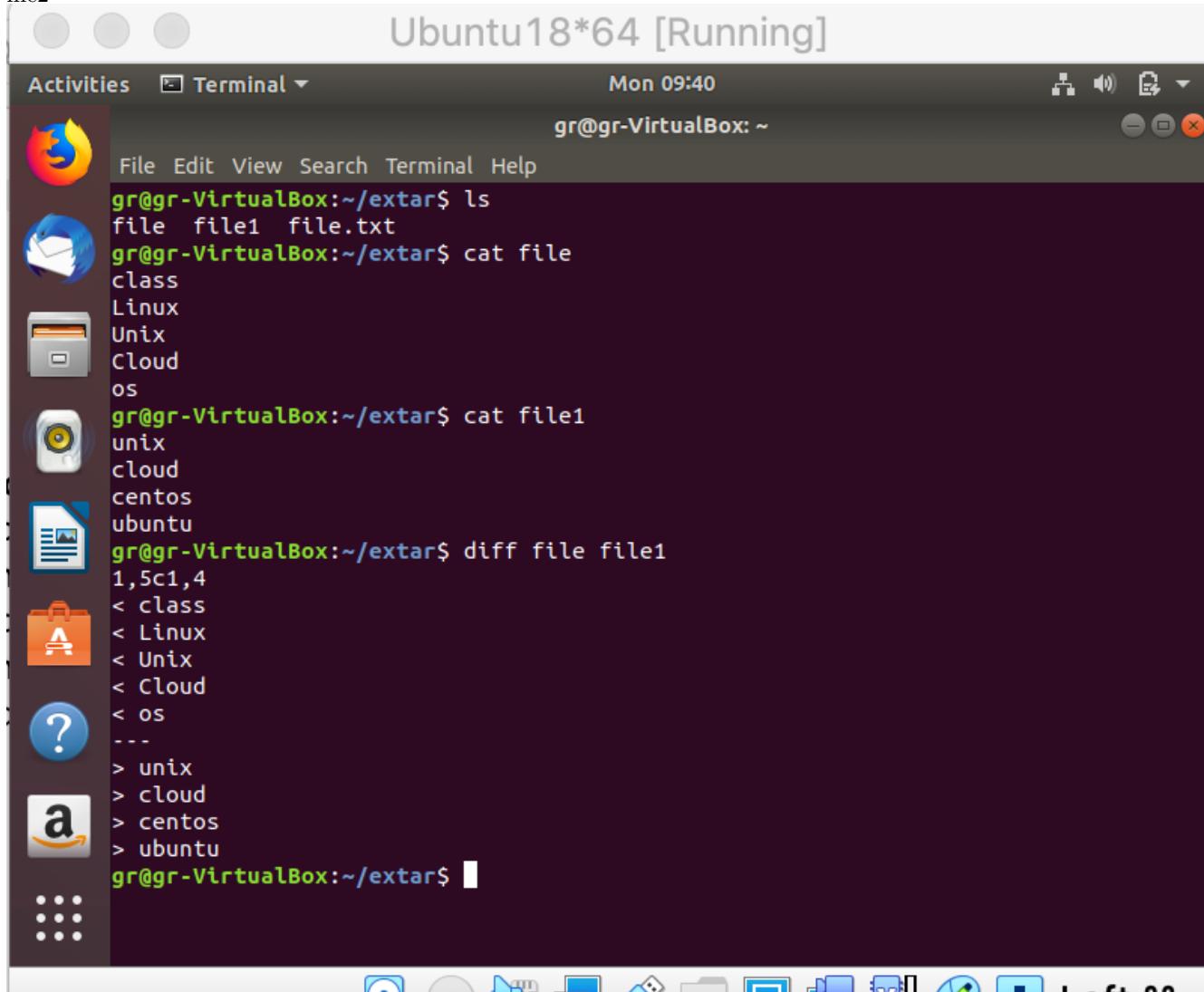


Ubuntu18*64 [Running]

Activities Terminal Sun 21:24 gr@gr-VirtualBox: ~

```
File Edit View Search Terminal Help
gr@gr-VirtualBox:~/extar$ cat file.txt
ex awk
awk ex2
awk ex
gr@gr-VirtualBox:~/extar$ awk '{print $1}' file.txt
ex
awk
awk
gr@gr-VirtualBox:~/extar$
```

35. diff - allows to compare two files line by line. It can also compare the contents of directories. Example: " diff file1 file2 "



Ubuntu18*64 [Running]

Activities Terminal Mon 09:40 gr@gr-VirtualBox: ~

```
File Edit View Search Terminal Help
gr@gr-VirtualBox:~/extar$ ls
file file1 file.txt
gr@gr-VirtualBox:~/extar$ cat file
class
Linux
Unix
Cloud
os
gr@gr-VirtualBox:~/extar$ cat file1
unix
cloud
centos
ubuntu
gr@gr-VirtualBox:~/extar$ diff file file1
1,5c1,4
< class
< Linux
< Unix
< Cloud
< os
---
> unix
> cloud
> centos
> ubuntu
gr@gr-VirtualBox:~/extar$
```

36. sort - sorts the contents of a text file, line by line. Example: " sort file "

Ubuntu18*64 [Running]

Activities Terminal Mon 09:44 gr@gr-VirtualBox: ~

File Edit View Search Terminal Help

```
gr@gr-VirtualBox:~/extar$ ls
file file1 file.txt
gr@gr-VirtualBox:~/extar$ cat file
class
Linux
Unix
Cloud
os
gr@gr-VirtualBox:~/extar$ sort file
class
Cloud
Linux
os
Unix
gr@gr-VirtualBox:~/extar$
```

37. export - It is used to mark variables and functions to be passed to child processes. The command will generate or display all exported variables Example: "export"

Ubuntu18*64 [Running]

Activities Terminal Mon 09:51 gr@gr-VirtualBox: ~

```
:F7=\\"E[15;2~:F8=\\"E[17;2~:F9=\\"E[18;2~:FA=\\"E[19;2~:\\
:FB=\\"E[20;2~:FC=\\"E[21;2~:FD=\\"E[23;2~:FE=\\"E[24;2~:kb=:\\
:K2=\\"EOE:kB=\\"E[Z:kF=\\"E[1;2B:kR=\\"E[1;2A:*4=\\"E[3;2~:\\
:*7=\\"E[1;2F:#2=\\"E[1;2H:#3=\\"E[2;2~:#4=\\"E[1;2D:%c=\\"E[6;2~:\\
:%e=\\"E[5;2~:%i=\\"E[1;2C:kH=\\"E[1~:@1=\\"E[1~:kH=\\"E[4~:\\
:@7=\\"E[4~:kN=\\"E[6~:kP=\\"E[5~:kI=\\"E[2~:kD=\\"E[3~:ku=\\"EOA:\\"
:kd=\\"EOB:kr=\\"EOC:kl=\\"EOD:km:"
```

```
declare -x TEXTDOMAIN="im-config"
declare -x TEXTDOMAINDIR="/usr/share/locale/"
declare -x USER="gr"
declare -x USERNAME="gr"
declare -x VTE_VERSION="5202"
declare -x WINDOW="0"
declare -x WINDOWPATH="1"
declare -x XAUTHORITY="/run/user/1000/gdm/Xauthority"
declare -x XDG_CONFIG_DIRS="/etc/xdg/xdg-ubuntu:/etc/xdg"
declare -x XDG_CURRENT_DESKTOP="ubuntu:GNOME"
declare -x XDG_DATA_DIRS="/usr/share/ubuntu:/usr/local/share:/usr/share:/var/lib/snapd/desktop"
declare -x XDG_MENU_PREFIX="gnome-"
declare -x XDG_RUNTIME_DIR="/run/user/1000"
declare -x XDG_SEAT="seat0"
declare -x XDG_SESSION_DESKTOP="ubuntu"
declare -x XDG_SESSION_ID="1"
declare -x XDG_SESSION_TYPE="x11"
declare -x XDG_VTNR="1"
declare -x XMODIFIERS="@im=ibus"
gr@gr-VirtualBox:~$
```

38. pwd - for printing the current working directory.

Ubuntu18*64 [Running]

Activities Terminal Mon 09:54 gr@gr-VirtualBox: ~

```
File Edit View Search Terminal Help
gr@gr-VirtualBox:~$ pwd
/home/gr
gr@gr-VirtualBox:~$
```

39. crontab - The crontab command opens the cron table for editing. The cron table is the list of tasks scheduled to run at regular time intervals on the system. Example: "crontab -e"

Ubuntu18*64 [Running]

Activities Terminal Mon 10:02 gr@gr-VirtualBox: ~

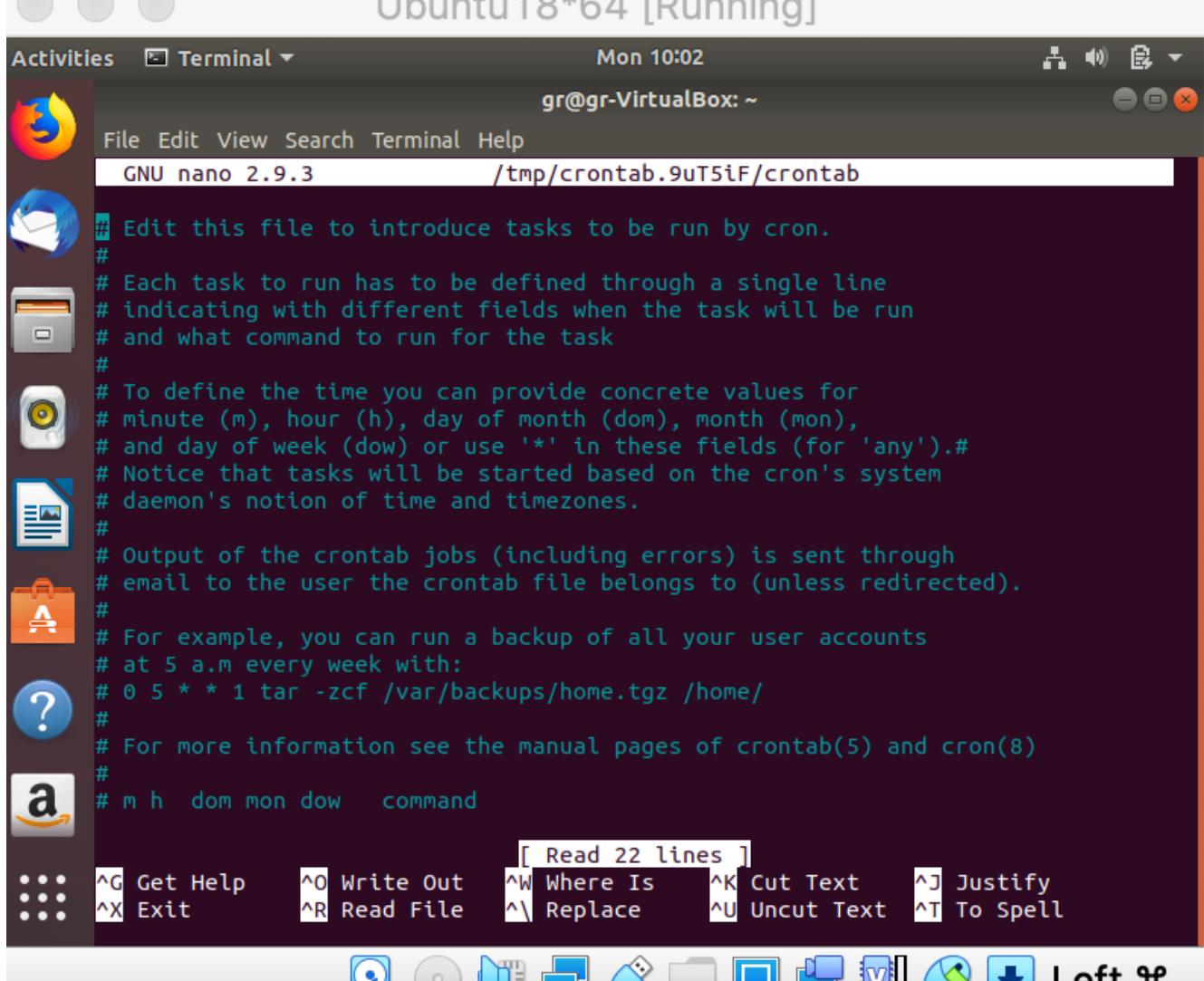
File Edit View Search Terminal Help
GNU nano 2.9.3 /tmp/crontab.9uT5iF/crontab

```
# Edit this file to introduce tasks to be run by cron.  
#  
# Each task to run has to be defined through a single line  
# indicating with different fields when the task will be run  
# and what command to run for the task  
#  
# To define the time you can provide concrete values for  
# minute (m), hour (h), day of month (dom), month (mon),  
# and day of week (dow) or use '*' in these fields (for 'any').#  
# Notice that tasks will be started based on the cron's system  
# daemon's notion of time and timezones.  
#  
# Output of the crontab jobs (including errors) is sent through  
# email to the user the crontab file belongs to (unless redirected).  
#  
# For example, you can run a backup of all your user accounts  
# at 5 a.m every week with:  
# 0 5 * * 1 tar -zcf /var/backups/home.tgz /home/  
#  
# For more information see the manual pages of crontab(5) and cron(8)  
#  
# m h dom mon dow command
```

[Read 22 lines]

^G Get Help ^O Write Out ^W Where Is ^K Cut Text ^J Justify
^X Exit ^R Read File ^A Replace ^U Uncut Text ^T To Spell

Left



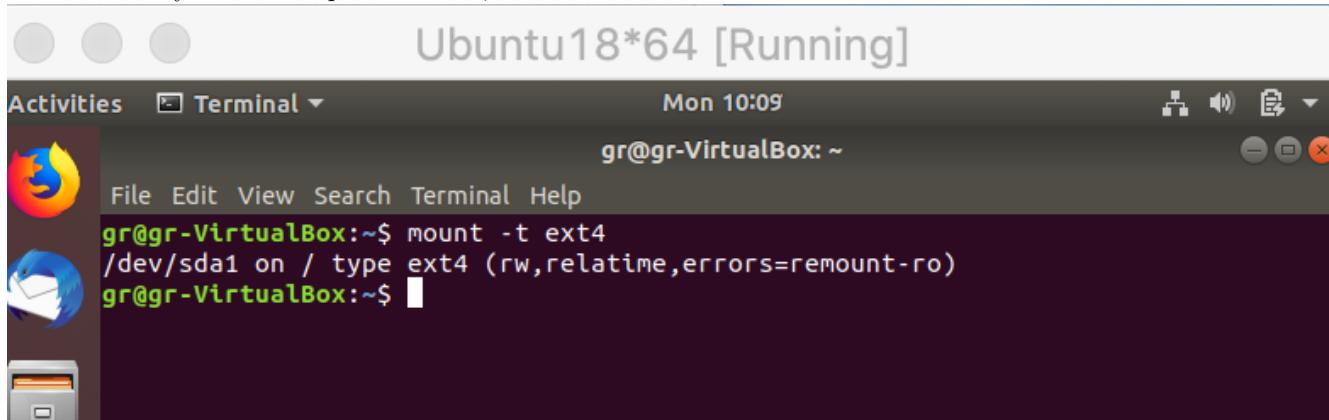
40. mount - To attach (mount) file systems and removable devices such as USB flash drives at a particular mount point in the directory tree. Example: "mount", "mount -t ext4"

Ubuntu18*64 [Running]

Activities Terminal Mon 10:09 gr@gr-VirtualBox: ~

File Edit View Search Terminal Help

```
gr@gr-VirtualBox:~$ mount -t ext4  
/dev/sda1 on / type ext4 (rw,relatime,errors=remount-ro)  
gr@gr-VirtualBox:~$
```



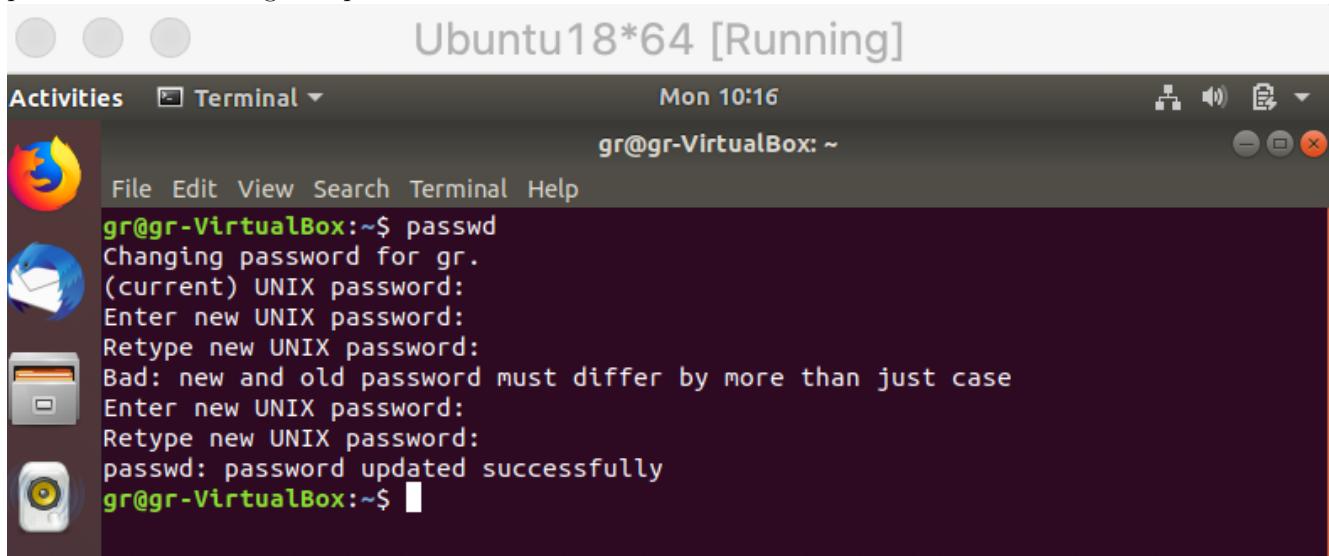
41. passwd - used to change the password of a user account

Ubuntu18*64 [Running]

Activities Terminal Mon 10:16 gr@gr-VirtualBox: ~

File Edit View Search Terminal Help

```
gr@gr-VirtualBox:~$ passwd  
Changing password for gr.  
(current) UNIX password:  
Enter new UNIX password:  
Retype new UNIX password:  
Bad: new and old password must differ by more than just case  
Enter new UNIX password:  
Retype new UNIX password:  
passwd: password updated successfully  
gr@gr-VirtualBox:~$
```



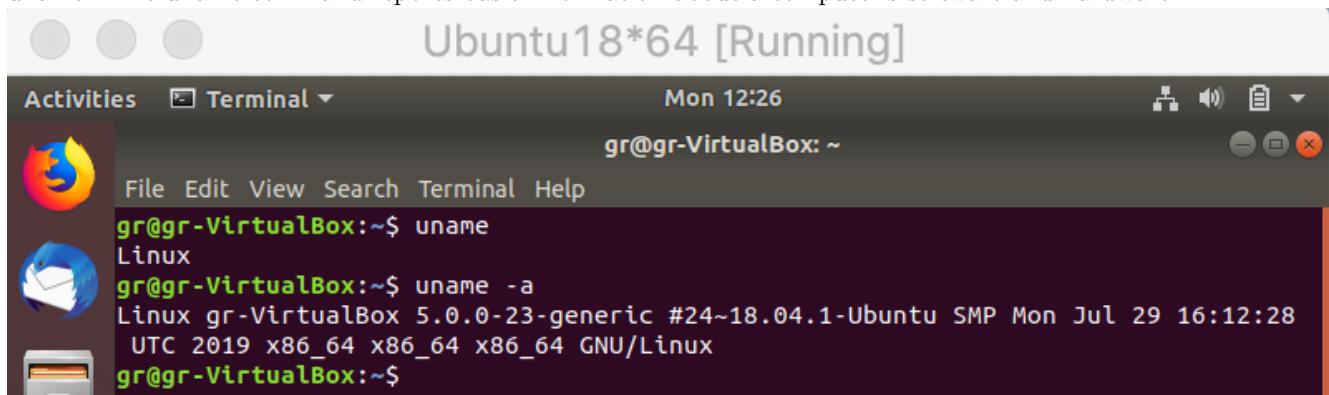
42. uname - The uname command reports basic information about a computer's software and hardware.

Ubuntu18*64 [Running]

Activities Terminal Mon 12:26 gr@gr-VirtualBox: ~

File Edit View Search Terminal Help

```
gr@gr-VirtualBox:~$ uname  
Linux  
gr@gr-VirtualBox:~$ uname -a  
Linux gr-VirtualBox 5.0.0-23-generic #24~18.04.1-Ubuntu SMP Mon Jul 29 16:12:28  
UTC 2019 x86_64 x86_64 x86_64 GNU/Linux  
gr@gr-VirtualBox:~$
```



43. whereis - Lets users locate binary, source, and manual page files for a command. Example: "whereis whereis"

```
Ubuntu18*64 [Running]
Activities Terminal Mon 12:38
gr@gr-VirtualBox:~$ whereis whereis
whereis: /usr/bin/whereis /usr/share/man/man1/whereis.1.gz
gr@gr-VirtualBox:~$
```

44. whatis - The whatis command provides very brief descriptions of command line programs Example: whatis cat

```
Ubuntu18*64 [Running]
Activities Terminal Mon 12:40
gr@gr-VirtualBox:~$ whatis cat
cat (1)           - concatenate files and print on the standard output
gr@gr-VirtualBox:~$
```

45. su - The Linux command 'su' is used to run commands as a different user. Example: su

```
Ubuntu18*64 [Running]
Activities Terminal Tue 10:22
gr@gr-VirtualBox:~$ sudo su gr2
[sudo] password for gr:
$ Thunderbird Mail
Password:
su: Authentication failure
$ su gr2
Password:
su: Authentication failure
$ exit
gr@gr-VirtualBox:~$
```

46. ping - one of the most used utilities for troubleshooting, testing, and diagnosing network connectivity issues Example: ping google.com

```
Ubuntu18*64 [Running]
Activities Terminal Tue 10:36
gr@gr-VirtualBox:~$ ping google.com
PING google.com (216.58.192.174) 56(84) bytes of data.
64 bytes from ord36s02-in-f14.1e100.net (216.58.192.174): icmp_seq=1 ttl=63 time=3.72 ms
64 bytes from ord36s02-in-f14.1e100.net (216.58.192.174): icmp_seq=2 ttl=63 time=3.89 ms
64 bytes from ord36s02-in-f14.1e100.net (216.58.192.174): icmp_seq=3 ttl=63 time=10.4 ms
64 bytes from ord36s02-in-f14.1e100.net (216.58.192.174): icmp_seq=4 ttl=63 time=3.92 ms
64 bytes from ord36s02-in-f14.1e100.net (216.58.192.174): icmp_seq=5 ttl=63 time=11.9 ms
64 bytes from ord36s02-in-f14.1e100.net (216.58.192.174): icmp_seq=6 ttl=63 time=11.1 ms
64 bytes from ord36s02-in-f14.1e100.net (216.58.192.174): icmp_seq=7 ttl=63 time=11.0 ms
64 bytes from ord36s02-in-f14.1e100.net (216.58.192.174): icmp_seq=8 ttl=63 time=10.7 ms
64 bytes from ord36s02-in-f14.1e100.net (216.58.192.174): icmp_seq=9 ttl=63 time=4.20 ms
64 bytes from ord36s02-in-f14.1e100.net (216.58.192.174): icmp_seq=10 ttl=63 time=7.84 ms
64 bytes from ord36s02-in-f14.1e100.net (216.58.192.174): icmp_seq=11 ttl=63 time=10.5 ms
64 bytes from ord36s02-in-f14.1e100.net (216.58.192.174): icmp_seq=12 ttl=63 time=10.6 ms
64 bytes from ord36s02-in-f14.1e100.net (216.58.192.174): icmp_seq=13 ttl=63 time=5.43 ms
64 bytes from ord36s02-in-f14.1e100.net (216.58.192.174): icmp_seq=14 ttl=63 time=
```

47. traceroute - prints the route that a packet takes to reach the host. Example: "traceroute -6 10 google.com"

Ubuntu18*64 [Running]

Activities Terminal Tue 15:33 gr@gr-VirtualBox: ~

Firefox Web Browser File Edit View Search Terminal Help

```
gr@gr-VirtualBox:~$ traceroute -F google.com
traceroute to google.com (216.58.192.174), 30 hops max, 60 byte packets
 1 _gateway (10.0.2.2)  0.432 ms  0.371 ms  0.348 ms
 2 104.194.96.1 (104.194.96.1)  5.121 ms  4.952 ms  4.965 ms
 3 216.47.159.165 (216.47.159.165)  4.846 ms  4.817 ms  4.698 ms
 4 5-2-3.bear2.Cincinnati1.Level3.net (4.71.182.25)  4.671 ms  4.397 ms  4.362
ms
 5 * * *
 6 72.14.203.208 (72.14.203.208)  4.139 ms  3.487 ms  3.675 ms
 7 * * *
 8 108.170.243.174 (108.170.243.174)  7.226 ms 74.125.251.46 (74.125.251.46)
6.437 ms 72.14.232.186 (72.14.232.186)  6.495 ms
 9 216.239.42.151 (216.239.42.151)  3.775 ms 108.170.243.175 (108.170.243.175)
 4.241 ms 108.170.243.197 (108.170.243.197)  6.328 ms
10 ord36s02-in-f174.1e100.net (216.58.192.174)  6.123 ms 209.85.241.124 (209.8
5.241.124)  6.125 ms  5.950 ms
```

48. date - command displays or sets the system date.

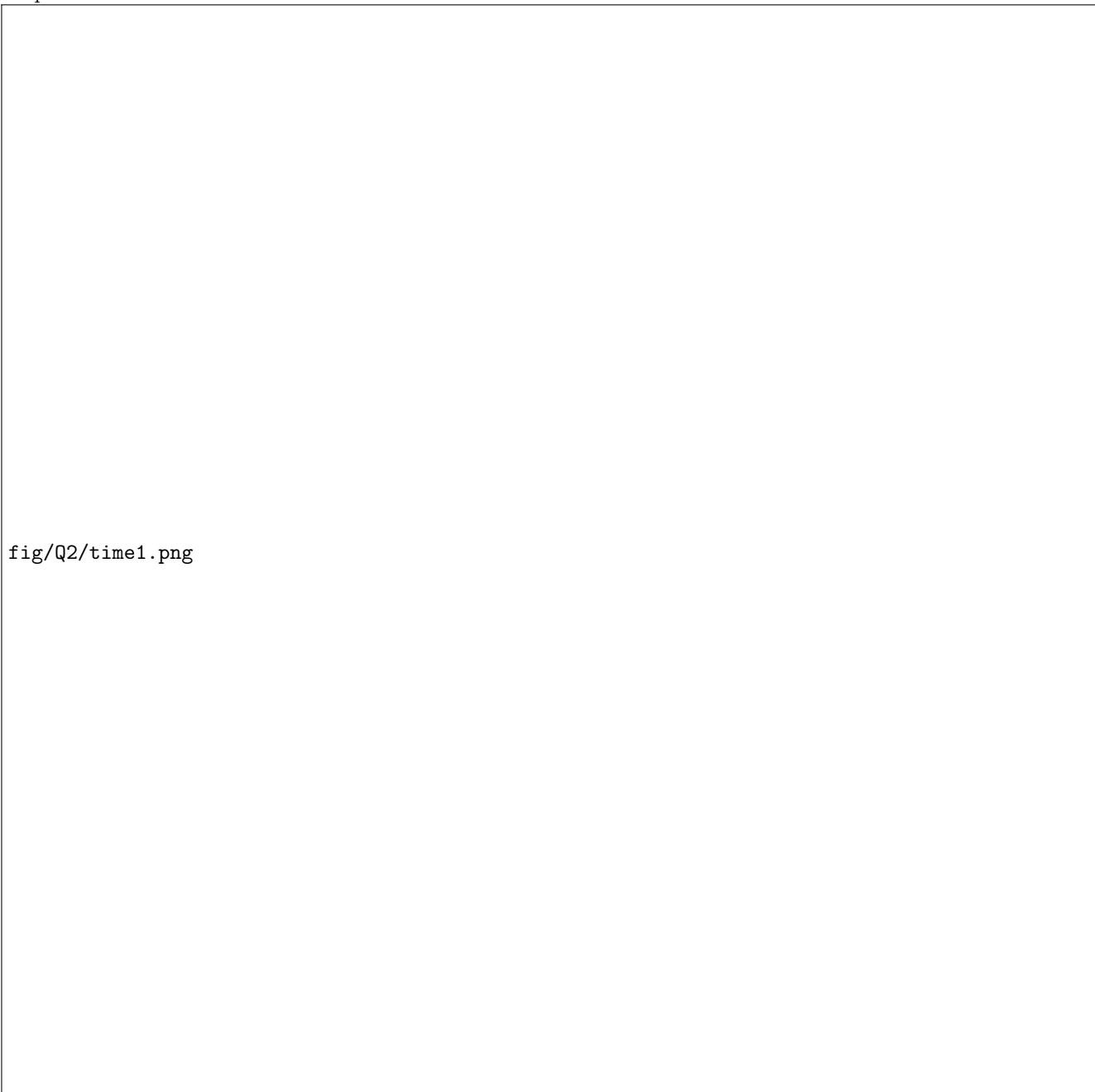
Ubuntu18*64 [Running]

Activities Terminal Tue 15:36 gr@gr-VirtualBox: ~

Firefox Web Browser File Edit View Search Terminal Help

```
gr@gr-VirtualBox:~$ date
Tue Jan 28 15:36:32 CST 2020
gr@gr-VirtualBox:~$
```

49. time - used to determine how long a given command takes to run. It is useful for testing the performance of your scripts and commands.



fig/Q2/time1.png

50. wget - for downloading files from the Internet. Example: wget "https://petition.parliament.uk/petitions?page=2state=all"

Ubuntu18*64 [Running]

Activities Terminal Tue 15:55
gr@gr-VirtualBox: ~

```
File Edit View Search Terminal Help
gr@gr-VirtualBox:~$ wget "https://petition.parliament.uk/petitions?page=2&state=all"
--2020-01-28 15:54:55-- https://petition.parliament.uk/petitions?page=2&state=all
Resolving petition.parliament.uk (petition.parliament.uk)... 13.249.134.48, 13.249.134.80, 13.249.134.107, ...
Connecting to petition.parliament.uk (petition.parliament.uk)|13.249.134.48|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: unspecified [text/html]
Saving to: 'petitions?page=2&state=all'

petitions?page=2&st      [ <=>          ]  25.73K  --.-KB/s  in 0.001s

2020-01-28 15:54:55 (38.9 MB/s) - 'petitions?page=2&state=all' saved [26347]
gr@gr-VirtualBox:~$
```

51. wc - for printing newline, word and byte counts for files. Example: wc file1

Ubuntu18*64 [Running]

Activities Terminal Tue 15:59
gr@gr-VirtualBox: ~/extar

```
File Edit View Search Terminal Help
gr@gr-VirtualBox:~$ cd extar
gr@gr-VirtualBox:~/extar$ ls
file file1 file.txt
gr@gr-VirtualBox:~/extar$ wc file1
4 4 26 file1
gr@gr-VirtualBox:~/extar$
```

52. pwgen - generates secure random passwords that are easy to remember.

Ubuntu18*64 [Running]

Activities Terminal Tue 16:02
gr@gr-VirtualBox: ~

```
File Edit View Search Terminal Help
gr@gr-VirtualBox:~$ pwgen
chieF3Ue zo0SohTi Tei9oyee Wai4ahyu aihoa3UF shePu4uu eid20hce Maimah3i
au8Nai0i EngeeKi3 aing3eiB aQuoh8oh aezou7Ah Blumi5ei feikie9U EVE4eidi
ain5neiD Leh9mieh maeNg2ao Ahloong3 Xae3AhQu Phi3suxo YaGh3uyi eiLahei0
Su5eoTha eeshiiH3 Dei7EiM6 Ooc3osuw QuaeZah5 VaWaequ2 aeza5Eeh See6uzoh
shooj8Hi ji3Aeroa leiSohm5 zeewei0R OhFee1oh thi9EeZa quohCh4r Eel1AeFu
Raen1xah Esefer5t uokah2La UofohTh4 ee0Theu6 Iecai6ha Nuicho4u vahKee0g
Phiephi2 ahm5Aici AC9cieWe odoG1pho aed5AiJ2 Mup3aep0 eangie9U Rahv9Cha
Toipe1pu piNg1ait Chai1ohj cua4eiBu Iejien0i eiY7chi0 De9eeloI eRoh2tai
iY4oj2Ur Uan6naya di7aek0I Re6IeCos Yiod0Xei Aekuqu2z Pheevie7 ug1ki0Lo
ahghiew4 ohTh7ahG eeg50c90 joVaecu0 ungoh4oZ aifooNg7 Agiu0uov eJieS3Ee
Aehahgh4 Aiz6Aawi ie70hzei bahkoo3U ohgahL40 oreel0C5 voh0Neuv uGhu0mie
Eangahw2 ohQuoo4x hoFei6li Soo1aet8 iMohg9tu jieG4nu0 WieP0she Eem4eeng
phaeM4oh EeSac3Ai ieJ1eeF9 Kahxah1n EiThie4e cohphu50 lu0Ieg9r Eerai1ai
oong6Vah aT8phohw nuaSh4ch Ielie0ci Tue10hDa YeuF3ru5 jaeZe15A oe6ahMai
aeGhu6sh eid9aiCh Iez7ceew Queey1Xu va0chooJ Daoxae0P SoZ5chiT Choh3qua
ta0sho2P Iegi2Eik aiZeeJ9o ix8jaiNg Tuso2nei oew4Moo8 pah0Thei ri2Ahkie
Xul5engi udai2Ahz Iez8iez5 Oow0uch9 raNgomo3 zait1ieD ieDie0uc AethooW0
OaD5eeSi foo4Mawo QuoeCh4e pooX0Dou Orei9eih ohRe4eim foNae7un Oo2oru3K
Ecile6uew jo8wooXa chaeR4se Du2aesho OhgahF6f thaNi2di dour6Ic8 ePei0och
Iedaeng7 Fagh8iso roozi1Qu Ezahvee3 Aajap90o thi6SeGi yoosh3Sh asoo8Aez
gr@gr-VirtualBox:~$
```

3 Question 3

- (a) Create dataset-generator.sh and run it for at least 10 seconds. We used 10M records, which made it last 48 seconds.

```

generate-dataset.sh x sort-data.sh x gen_sort_time_data.txt x
1 #!/bin/bash
2 if [ $# != 2 ]
3 then
4     echo "Arguments: [filename] [num_records]"
5     exit -1
6 fi
7
8 filename=$1
9 num_records=$2
10 temp1="$filename.int1"
11 temp2="$filename.int2"
12 temp3="$filename.str"
13
14 #Initialize output file
15 : > $filename
16 #Generate a bunch of 32-bit random numbers
17 shuf -i 0-4294967296 -n $num_records > $temp1
18 shuf -i 0-4294967296 -n $num_records > $temp2
19 #Generate a bunch of 100-byte ASCII strings
20 base64 -i /dev/urandom | fold -w 100 | head -n $num_records > $temp3
21 #[int1] [int2] [str]
22 paste $temp1 $temp2 $temp3 > $filename
23
lukemartinlogan@lukemartinlogan-mint-desktop2:~
```

File Edit View Search Terminal Help

lukemartinlogan@lukemartinlogan-mint-desktop2:~\$ time bash generate-dataset.sh df10M.txt 10000000

real 0m48.453s
user 0m43.049s
sys 0m14.797s

```

generate-dataset.sh x sort-data.sh x analyze.py x part3_record.csv x df1K.txt x
1 1894848385 3620963883 BCyU2nz6qgmR6eu/MZjoVRxrAeGdWsf9HLA7qilhCDTRahmH9uqr09fcnJZMncyJwwU6TzaDb2+7
2 3778744166 1819418239 AVSieep6S4Q//BEil7g8k0X+zlyYIUCfkqtTDe5EwzMbLoIWJldwjZMBgo5ws2UZUw7eVvPp1YVY
3 1684465868 2405376001 NNJpxN4totn+dRbAl/f8HG9mIk2EaqC0l79dRi/+KeaVosw9FW3WRe0mEhNESbYn3pao5NjPmH1b
4 4081950717 443854366 AvVLUFueyt7NppSY3VRsElYD1dPxsmDqzWKkmzpmA0+Lcoisft1HHWiz6TxZ+8KkZiS2s1zbQk8
5 1699881873 2656745701 kqK/OuVzo55Bj44fLVeskyZYsGKnV0asYs2z2QmkLNnsa8RjoHuyDSmh8Mldv8sjslQqbHrsD34jN
6 480708116 1657770731 52yEa9oZU/4UsR9nG0Ya+VgIC/0HTAjHNputTyZm787vc92w0KDj8J487pcyfAkampbJ2DznqYb
7 4050438582 1183779633 t2lW6QJrYSxCs90A/FJed3dE+YzgdAR6Nro0Y5P0PP4M8AKnr1lc+cdslfTud8zIfwqodR+PgJ49
8 281334557 2204635171 eeLPNg9AIteirJB4NCu7Cb4l8YNN0ZewoJnyRadvLSZTUGU2yAjzzHl+0JH0L4Vx6UXjh4zzhhI
9 2981612357 4191686263 YENwWIbSBiQ4xDAsr6vHEw1nYt5xrh2jTTv0G855rTmNrX3APh2mVpfB5DsKRARTdeCGgmPvnYi
10 2032241873 2616424531 slGarV/YCZMNeIJgASXU0WB7vsZyzKx6wTKkjduKwzfzMMjEGqxAqGGHI2F3eRsH73DcDhoM81p67
11 1819258040 2126861352 P3f3B0Llf6Ntr9PI7gU1CUBeVn0+B07xhugsYDC0Ee9WN2IiCKbJS1xasw0+iV/CNOVo08RtuY0T
12 927801269 2288059340 MS0LBV0eEHQ NayQCL3xJ1vIN4pBaxIeCb7rsffdq1lzTFDh2Y38ewMeuhqsYRIq1E0slebGBZBu6
13 349065368 2525413207 Jqo7KaGpWTvgdVvFNaffVmuf08WzMAMwrxCDeseMf2RgZViWYSx5m+zcndPFtsLGGP5Tsxy0JqH
```

- (b) Create sort-data.sh and run it on the previous dataset

```

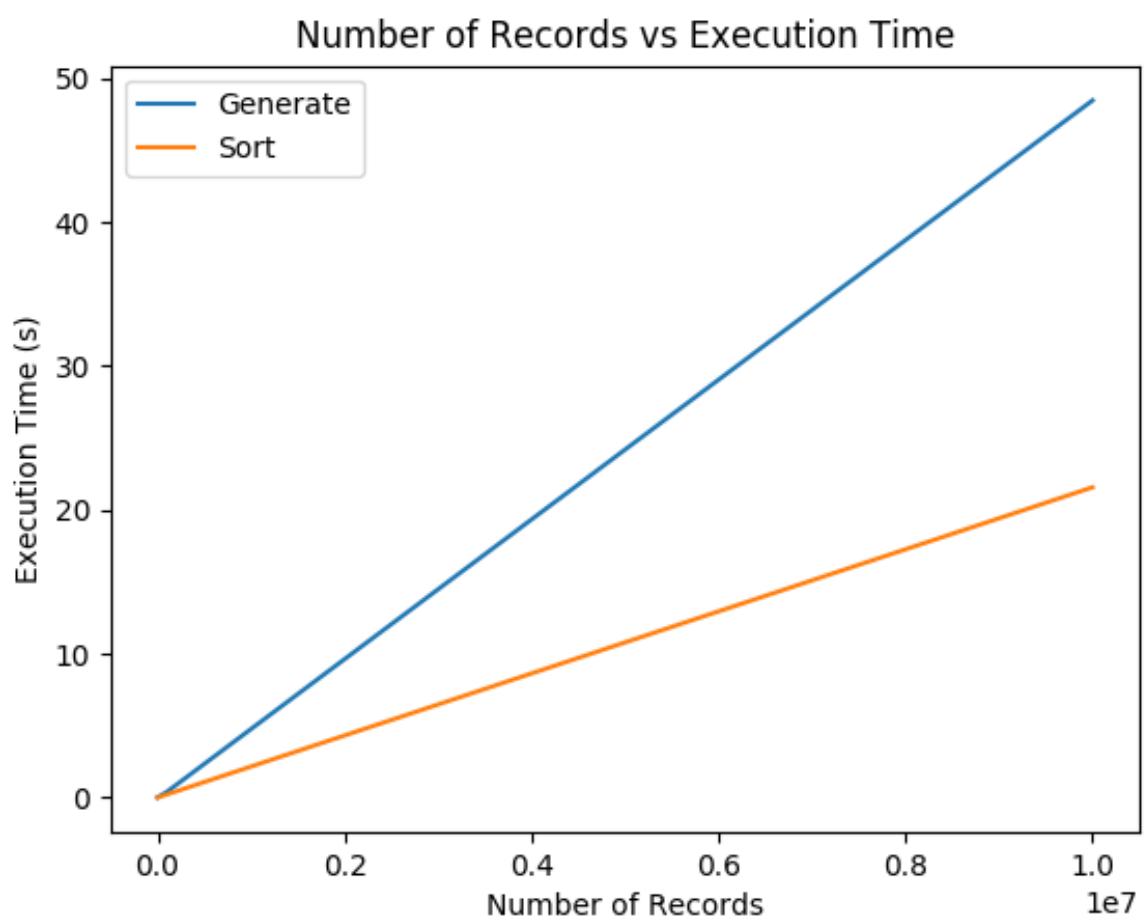
generate-dataset.sh x sort-data.sh x df.txt x df.txt.sorted x
1 #!/bin/bash
2 if [ $# != 1 ]
3 then
4     echo "Arguments: [filename]"
5     exit -1
6 fi
7
8 filename=$1
9 sort -k1 -n $filename -o "$filename.sorted"
10
lukemartinlogan@lukemartinlogan-mint-desktop2:~
```

File Edit View Search Terminal Help

lukemartinlogan@lukemartinlogan-mint-desktop2:~\$ time bash sort-data.sh df10M.txt

real 0m21.569s
user 0m36.640s
sys 0m6.877s

- (c) Generate datasets of size 1K, 100K, 10M and then sort them. A plot of the execution time is shown below.



4 Question 4

- (a) Changing the number of cores in the VM increases increases the number of physical cores the VM can use to do work. By changing the number of cores in the VM, the performance of the VM began to increase. You will want to set the number of cores to a minimum if a lot of work needs to be done by the OS (outside of the VM). You will want to set the number of cores to the maximum if a lot of work needs to be done by the VM. However, this is risky because the OS may not get enough processing resources and can cause the VM to become sluggish or the computer to crash.
- (b)
- **None:** Specifying none directly turns off exposing to paravirtualization interface.
 - **Default:** The default option, when starting the VM, will pick a suitable interface depending on the type of guest OS. This is the default option selected during creation of new VMs.
 - **Legacy:** The legacy option is selected for VMs that were created with older versions of VirtualBox, and will select a paravirtualization interface when starting VM with VirtualBox 5.0 and newer.
 - **Minimal:** Announces the existence of a virtual environment. In addition, reports the frequency of TSC and APIC to the guest operating system. This provider is required to run any Mac OS X guests.
 - **KVM:** Provides a Linux KVM hypervisor module that is accepted by Linux kernels from version 2.6.25 onward. Implementation of VirtualBox currently supports paravirtualized clocks and SMP spinlocks . Recommended for Linux guests (including Ubuntu).
 - **Hyper-V:** Uses a Microsoft Hyper-V hypervisor interface that Windows 7 and newer operating systems recognizes. Implementation of VirtualBox currently supports paravirtualized clocks, reporting of APIC frequencies, guest debugging, guest crash reporting and relaxed timer checks. This provider is recommended for windows guests
- (c)
- **IDE** (Integrated Drive Electronics) is a standard electronic interface used between a computer motherboard's data paths or bus and the computer's disk storage devices. The IDE interface is based on the IBM PC Industry Standard Architecture (ISA) 16-bit bus standard, but it is also used in computers that use other bus standards. Useful for legacy OSes (that don't support other device controllers).
 - **A SATA controller** (serial ATA controller) is a hardware interface that connects a hard drive to a computer's motherboard and manages or directs the flow of data. Useful when you need to connect up to 30 storage devices to the VM.
 - **NVMe** (Non-Volatile Memory Express) is an interface protocol built especially for Solid State Drives (SSDs). NVMe works with PCI Express (PCIe) to transfer data to and from SSDs. NVMe enables rapid storage in computer SSDs and is an improvement over older Hard Disk Drive (HDD) related interfaces such as SATA and SAS. Useful if you need to connect up to 255 storage devices to the VM.
- (d)
- **Not attached:** A network card exists, but there is no connection. Good to use if your VM is only doing offline computational work.
 - **NAT:** Mask all network activity as if it came from your Host OS, although the VM can access external resources. Good if all you want to do is browse the web or download files in the VM.
 - **Bridged Adapter:** Connects to one of your local network cards and exchanges network packets directly without going through the host. Ie, it communicates directly with the outside world. Useful for network simulations and running servers.
 - **Internal Network:** Similar to bridged networking in that the VM can directly communicate with the outside world. However, the "outside world" is limited to other VMs on the same host which connect to the same internal network. Useful for testing server software.
 - **Host-only:** Create a network containing the host and a set of virtual machines local to the host. The VMs are not connected to the internet, but rather to each other and the host. Useful for testing client/server software.
 - **Generic adapter:** Used to interconnect virtual machines running on different hosts directly over an existing network. Like an internal network, except the VMs are not on the same host. Useful for testing server software in a distributed environment.
- (e)
- **USB 1.1 UHCI** (Universal Host Controller Interface) is supported for all virtual machine hardware versions.
 - **USB 2.0 EHCI** (Enhanced Host Controller Interface) controllers are supported if the virtual machine hardware is compatible with Workstation 6 and later virtual machines.
 - **USB 3.0 xHCI** (Extensible Host Controller Interface) support is available for Linux guests running kernel version 2.6.35 or later and for Windows 8 guests. The virtual machine hardware must be compatible with Workstation 8 or later virtual machines.

5 Question 5

- (a) A core is a physical processing unit on a processor. A hardware thread is the logical entity that executes instructions on a core. Hardware threads can make a single CPU core appear as multiple cores to an OS.
- (b) (a) INTEL XEON PLATINUM 9282 PROCESSOR
56 cores
112 threads
2.6GHz per core base frequency
3.8 GHz max frequency
77MB cache
400W power consumption
\$25,000 - \$50,000
- (b) AMD EPIC 7742
64 cores
128 threads
2.25GHz per core base frequency
3.4GHz per core max frequency
256MB cache
225W power consumption
\$6950
- (c) IBM Power LC922
44 cores
2.6GHz base frequency
512KB L2 cache per core
10MB L3 cache per core
\$7,999
- (d) ThunderX_Chip
48 cores
2.5 GHz base frequency
16MB shared L2 cache
78K l-cache per core
32K D-cache per core
\$6,399
- (e) NVIDIA TITAN RTX
24GB GDDR6
384-bit memory interface
1770MHz per core
4608 CUDA cores
576 Tensor cores
72 RT cores
280W power consumption
\$2500
- (c) We do not have 1THz processors today due to energy and heat cost. By making processors faster, the number of transistors increase making power consumption and heat increase drastically. In order to reduce the energy and heat cost, we have created multi-core processors that are slower (but more energy-efficient) per-core, but allow for applications to run in parallel.
- (d) Moore's Law states that the number of transistors on a single die will double every 18 months. However, transistors are made out of silicon, and silicon atoms cannot be divided to form more silicon atoms. A single silicon atom is approximately .2nm in diameter. Currently, processors have around 14nm lithography (which should halve when the number of transistors double). Thus, $14/2^{n/18} = .2 \implies n = 18 * \lg(14/.2) \approx 110$. Thus Moore's Law should be ending in no more than 110 months (9 years).

6 Question 6

- (a) Threading is useful on a single-core processor due to blocking states. When a thread performs time-consuming actions like IO, it will end up waiting for that IO operation to complete before going to the next instruction. During this time, another thread can be executed.
- (b) Having more threads does not always imply better performance. Threads typically require some degree of synchronization (since threads share the same memory space). If your code requires a lot of synchronization, threading will likely hinder performance. Furthermore, your processor can only execute a finite number of threads at once.
- (c) Super-linear speedup is possible through caching. Caches are orders of magnitude faster than main memory, making code that makes effective use of cache exponentially faster than code that makes ineffective use of the cache.
- (d) Locks are necessary in multi-threaded programs in order to maintain memory consistency. If multiple threads access the same memory regions at the same time without synchronization (locking), data can become corrupted.
- (e) It makes sense to limit the number of threads in a server process. Each thread requires its own stack space, which can become expensive if the number of threads go unchecked. Furthermore, having more threads will not guarantee a performance increase.