

Q1 Virtual Machine Setup

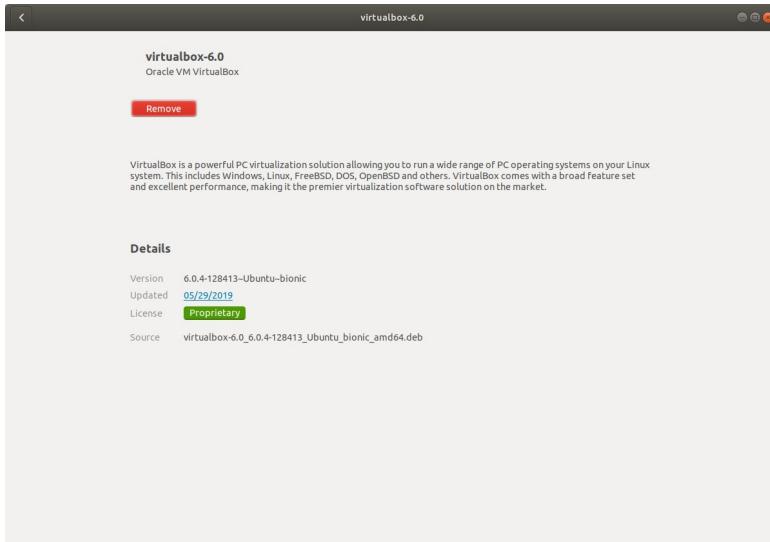
a. Linux White Paper - Downloaded from

<http://www.oracle.com/us/technologies/virtualization/oracle-vm-virtualbox-overview-2981353.pdf>

b. Download Oracle VirtualBox 6.0



c. Install VirtualBox



d. Download Ubuntu 18.04 Linux ISO Image

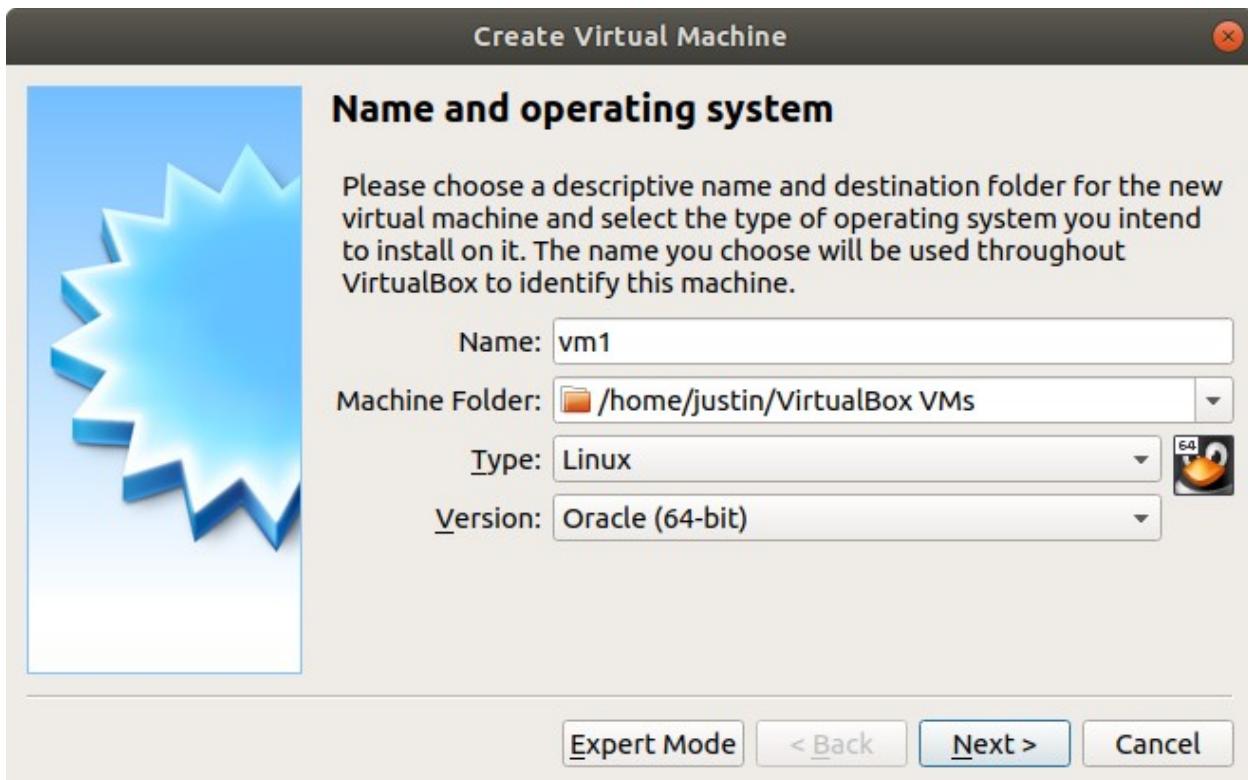
The screenshot shows a web browser window with the following details:

- Tab bar: CS 550 | Class Profile | Pia... | Course Content | Download_Old_Builds_6 | Index of /releases/18.04.1
- Address bar: Not secure | old-releases.ubuntu.com/releases/18.04.1/
- Content area:
 - Ubuntu 18.04 LTS (Bionic Beaver)**
 - Select an image**
Ubuntu is distributed on two types of images described below.
 - Desktop image**
The desktop image allows you to try Ubuntu without changing your computer at all, and at your option to install it permanently later. This type of image is what most people will want to use. You will need at least 1024MB of RAM to install from this image.
There is one image available:
 - 64-bit PC (AMD64) desktop image**
Choose this if you have a computer based on the AMD64 or EM64T architecture (e.g., Athlon64, Opteron, EM64T Xeon, Core 2). Choose this if you are at all unsure.
 - Server install image**
The server install image allows you to install Ubuntu permanently on a computer for use as a server. It will not install a graphical user interface.
There is one image available:
 - 64-bit PC (AMD64) server install image**
Choose this if you have a computer based on the AMD64 or EM64T architecture (e.g., Athlon64, Opteron, EM64T Xeon, Core 2). Choose this if you are at all unsure.
If you require LVM, RAID, multipath, network vlans, or network interface bonding during the installation; if you need to reuse existing partitions on your installation disk; or for support for other architectures besides AMD64/EM64T, see the [alternative images location](#).
A full list of available files, including [BitTorrent](#) files, can be found below.
If you need help burning these images to disk, see the [Image Burning Guide](#).
- File list table:

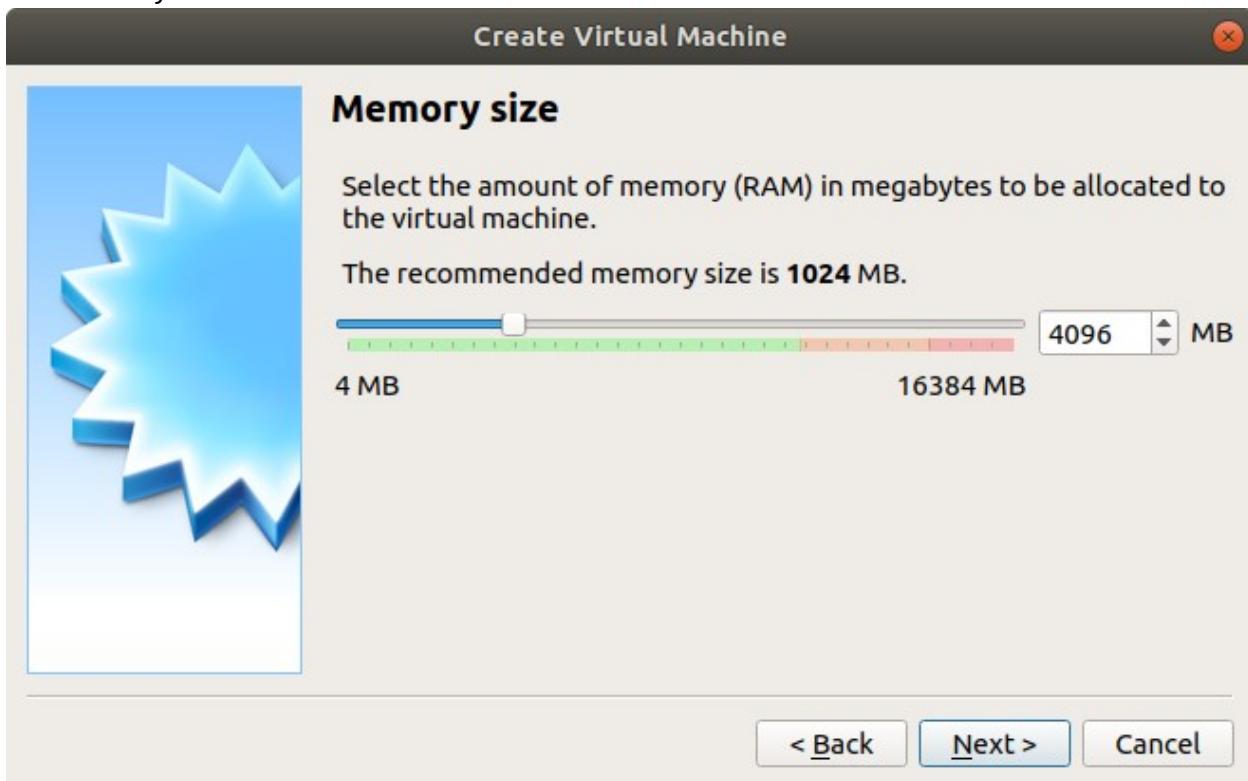
Name	Last modified	Size	Description
Parent Directory		-	
FOOTER.html	2018-04-26 20:59	27	
HEADER.html	2018-04-27 00:54	2.3K	
MD5SUMS	2019-08-08 12:27	1.7K	
MD5SUMS-metalink	2018-04-26 21:00	144	
MD5SUMS-metalink.gpg	2018-04-26 21:00	916	
MD5SUMS.gpg	2019-08-08 12:27	916	
SHA1SUMS	2019-08-08 12:27	1.9K	
SHA1SUMS.gpg	2019-08-08 12:27	916	
SHA256SUMS	2019-08-08 12:27	2.4K	
- Bottom navigation: ubuntu-18.04....iso | virtualbox-6.....deb

e. Virtual Machine Creation

e.1.



e.2. Memory allocation - 4GB



e.3. Virtual hardisk creation



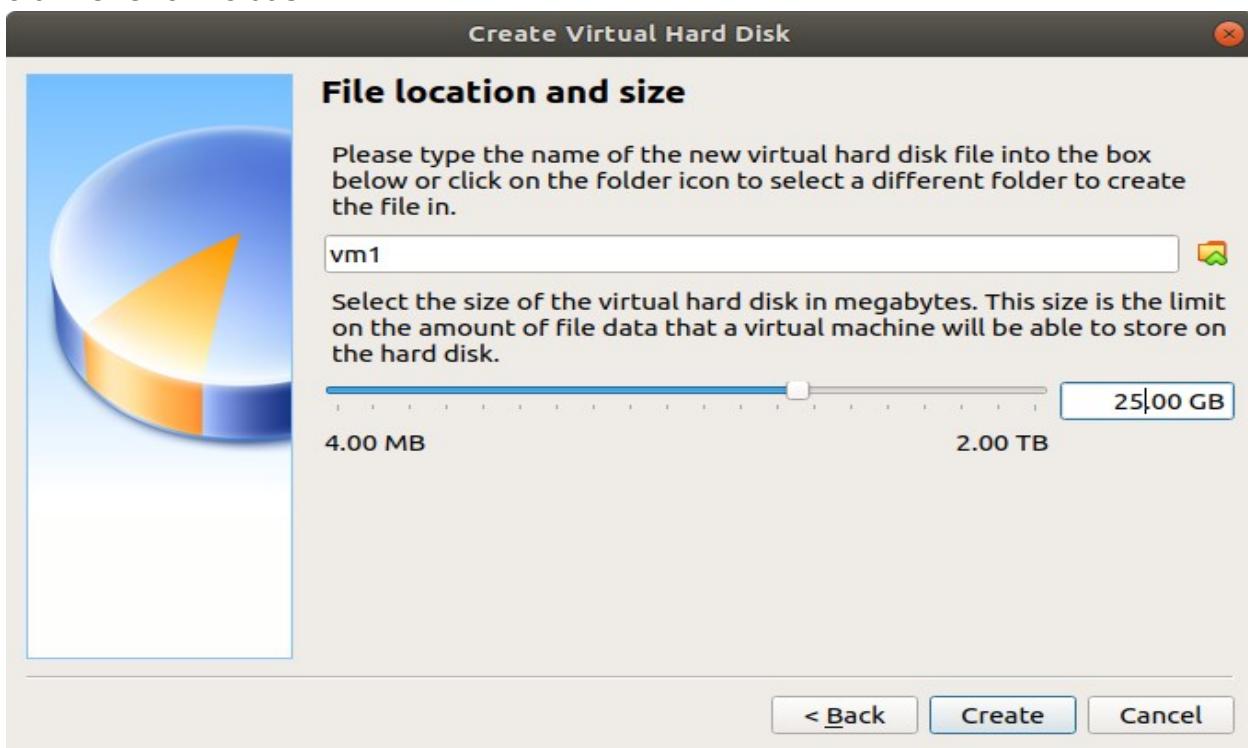
e.4. Virtual hardisk type - VDI



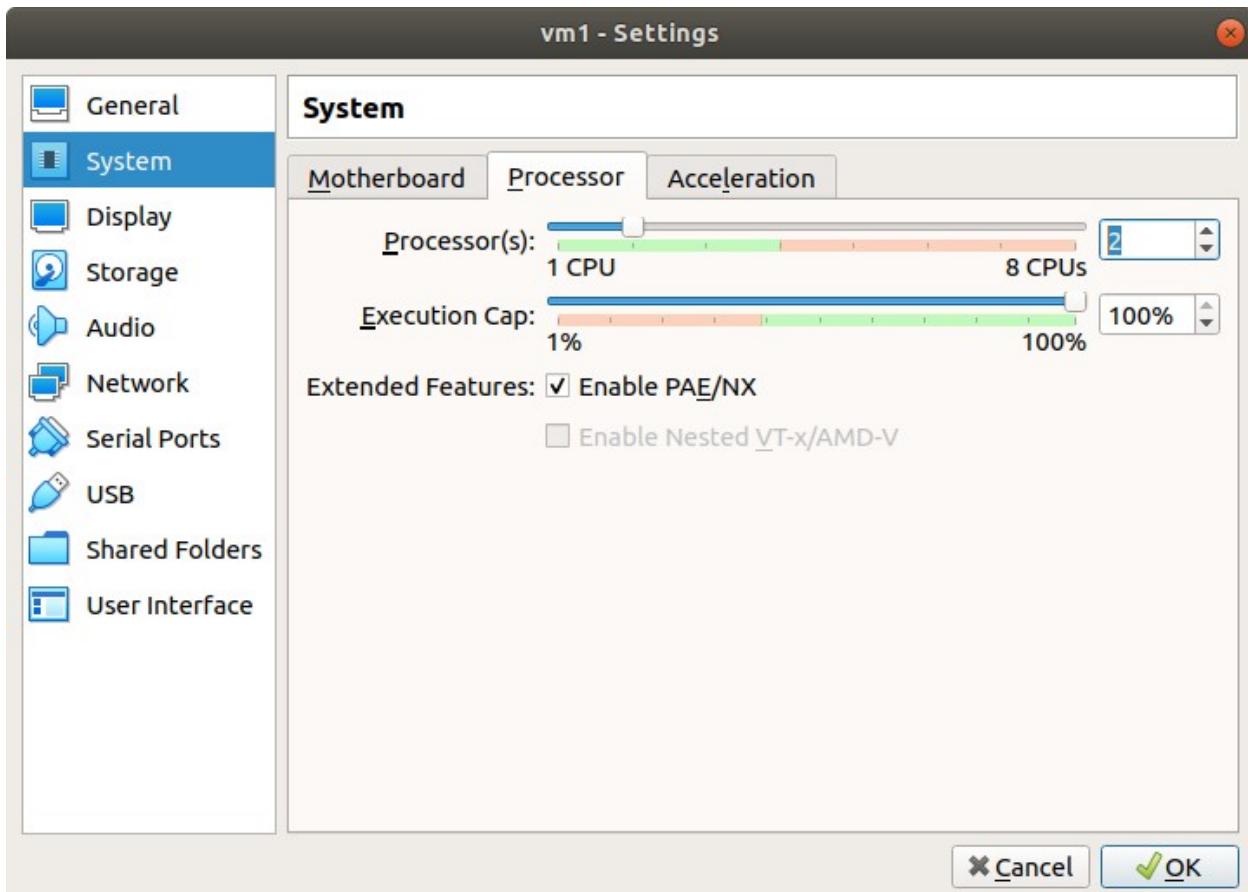
e.5. Dynamically allocated disk



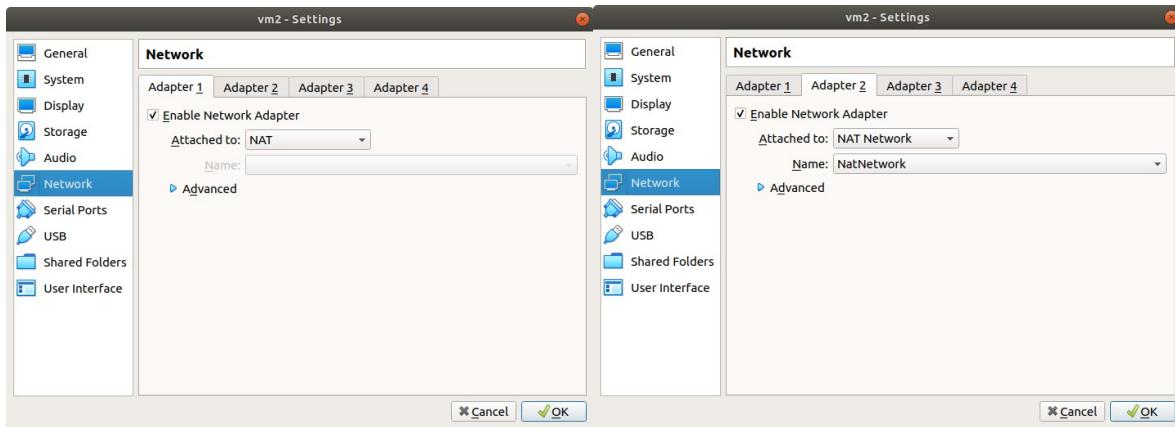
e.6. Disk size - 25.00GB



e.7. Processor - 1->2



e.8. Network settings, NAT(adapter1) and NAT network(adapter2)

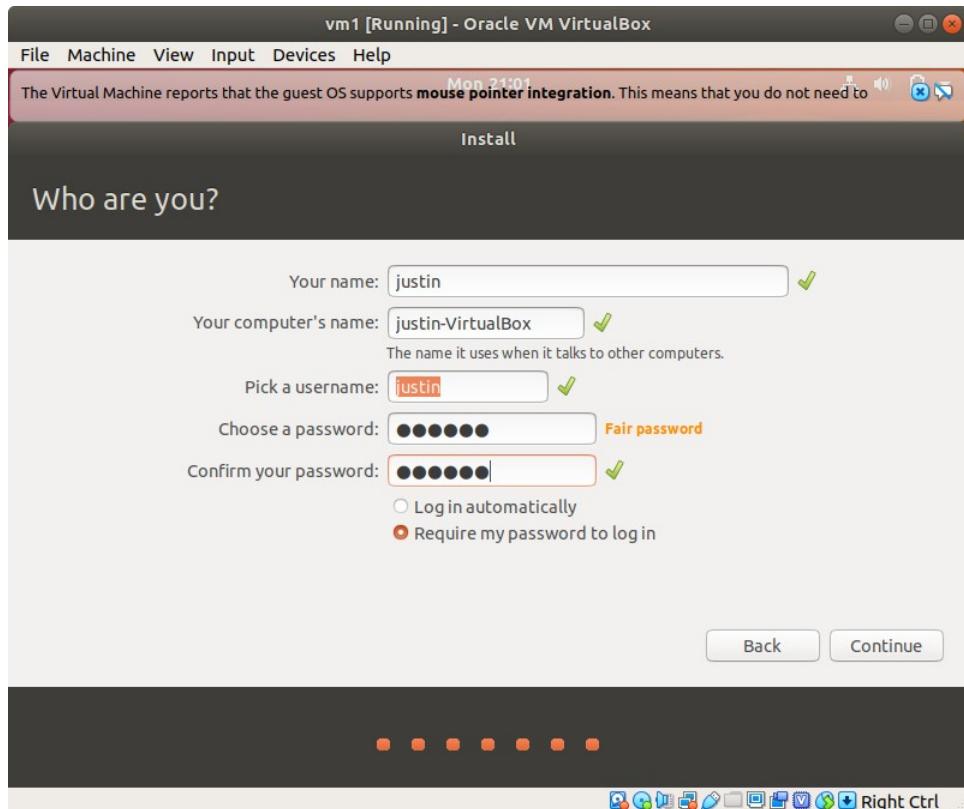


f. Ubuntu Installation

f.1. Select the downloaded ISO Image



f.2. Setup user account



h. i. Turn on firewall (ufw) and block all ports. Open port for ssh and enable ssh access.

The screenshot shows a terminal window titled "vm1 [Running] - Oracle VM VirtualBox". The terminal session is as follows:

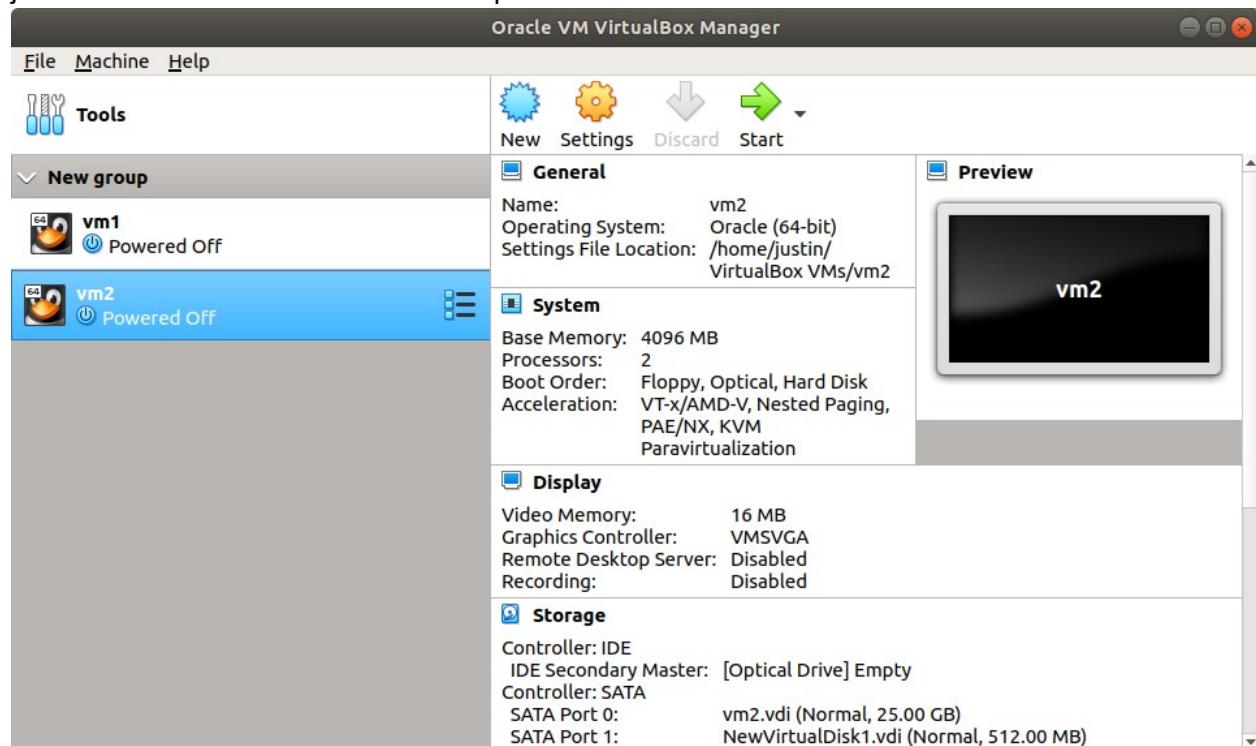
```
justin@justin-VirtualBox:~$ sudo ufw allow OpenSSH
Rule added
Rule added (v6)
justin@justin-VirtualBox:~$ sudo ufw status
Status: active

To           Action      From
--           ----       ---
OpenSSH      ALLOW       Anywhere
OpenSSH (v6) ALLOW       Anywhere (v6)

justin@justin-VirtualBox:~$ sudo systemctl status ssh
● ssh.service - OpenBSD Secure Shell server
   Loaded: loaded (/lib/systemd/system/ssh.service; enabled; vendor preset: ena
   Active: active (running) since Mon 2019-08-26 22:05:32 CDT; 8min ago
     Process: 3933 ExecStartPre=/usr/sbin/sshd -t (code=exited, status=0/SUCCESS)
   Main PID: 3934 (sshd)
      Tasks: 1 (limit: 4682)
        CGroup: /system.slice/ssh.service
                  └─3934 /usr/sbin/sshd -D

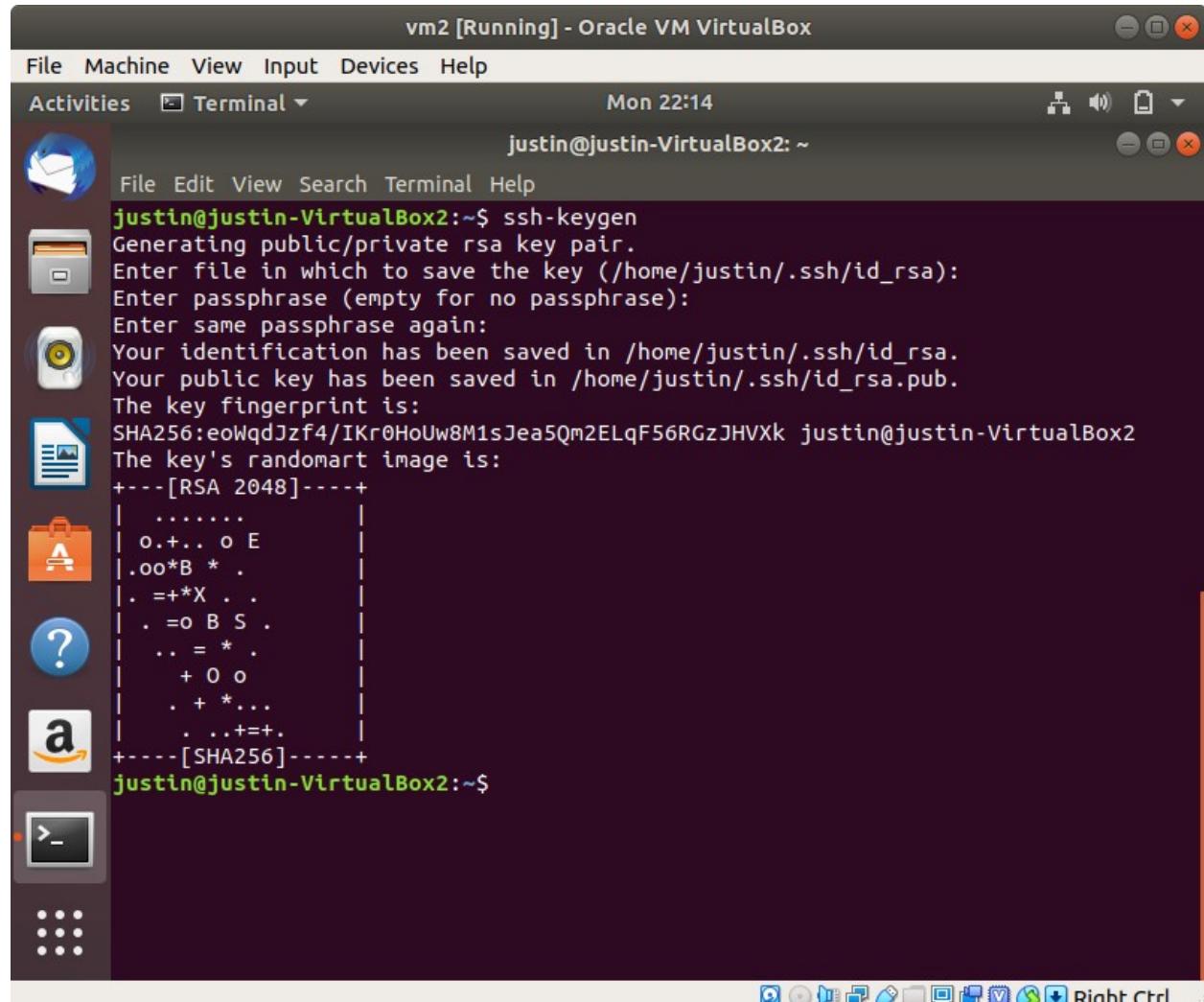
Aug 26 22:05:32 justin-VirtualBox systemd[1]: Starting OpenBSD Secure Shell ser
Aug 26 22:05:32 justin-VirtualBox sshd[3934]: Server listening on 0.0.0.0 port
Aug 26 22:05:32 justin-VirtualBox sshd[3934]: Server listening on :: port 22.
Aug 26 22:05:32 justin-VirtualBox systemd[1]: Started OpenBSD Secure Shell serv
justin@justin-VirtualBox:~$
```

j. Create another VM with the same specification



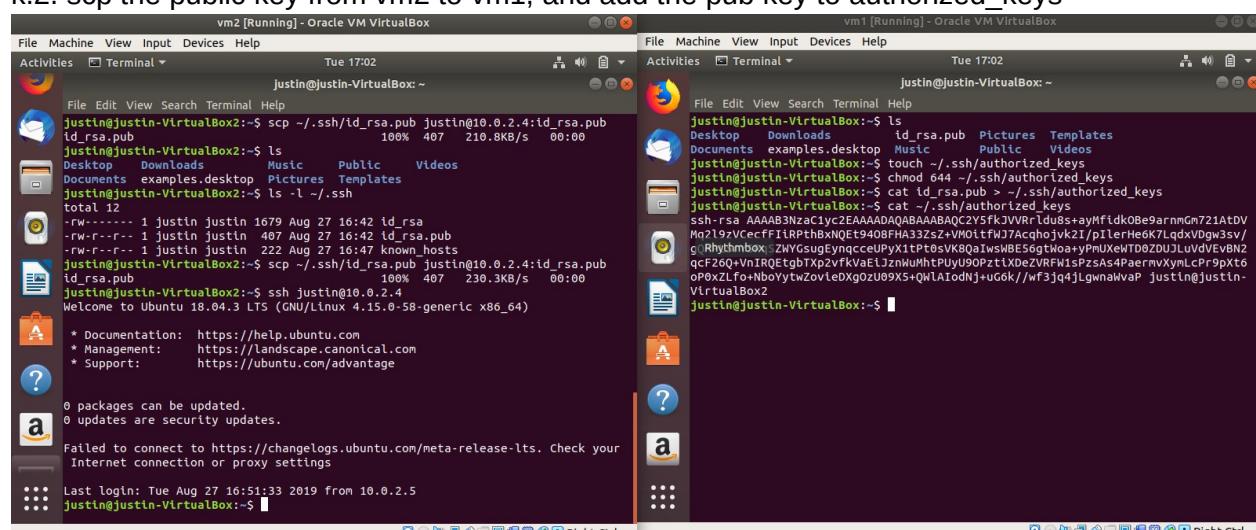
k. Create public/private keys, and install them for ssh authentication.

k.1. Create public/private key pair in vm2



```
justin@justin-VirtualBox2:~$ ssh-keygen
Generating public/private rsa key pair.
Enter file in which to save the key (/home/justin/.ssh/id_rsa):
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /home/justin/.ssh/id_rsa.
Your public key has been saved in /home/justin/.ssh/id_rsa.pub.
The key fingerprint is:
SHA256:eoWqdJzf4/IKr0HoUw8M1sJea5Qm2ELqF56RGzJHVXk justin@justin-VirtualBox2
The key's randomart image is:
+---[RSA 2048]---+
|.....|
|o.+.. o E|
|.oo*B * .|
|.=+*X . .|
|. =o B S .|
|.. = * .|
|+ O o|
|. + *...|
| . .+=+. |
+---[SHA256]---+
justin@justin-VirtualBox2:~$
```

k.2. scp the public key from vm2 to vm1, and add the pub key to authorized_keys



```
justin@justin-VirtualBox2:~$ scp -r .ssh/id_rsa.pub justin@10.0.2.4:id_rsa.pub
id_rsa.pub                                100% 407   210.8K/s  00:00
justin@justin-VirtualBox2:~$ ls
Desktop  Downloads  Music  Public  Videos
Documents examples.desktop  Pictures  Templates
justin@justin-VirtualBox2:~$ ls -l ~/.ssh
total 12
-rw-r--r-- 1 Justin Justin 1679 Aug 27 16:42 id_rsa
-rw-r--r-- 1 Justin Justin  407 Aug 27 16:42 id_rsa.pub
-rw-r--r-- 1 Justin Justin  222 Aug 27 16:47 known_hosts
justin@justin-VirtualBox2:~$ scp -r .ssh/id_rsa.pub justin@10.0.2.4:id_rsa.pub
id_rsa.pub                                100% 407   230.3K/s  00:00
justin@justin-VirtualBox2:~$ ssh justin@10.0.2.4
Welcome to Ubuntu 18.04.3 LTS (GNU/Linux 4.15.0-58-generic x86_64)

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

0 packages can be updated.
0 updates are security updates.

Failed to connect to https://changelogs.ubuntu.com/meta-release-lts. Check your
Internet connection or proxy settings

Last login: Tue Aug 27 16:51:33 2019 from 10.0.2.5
justin@justin-VirtualBox2:~$
```

```
justin@justin-VirtualBox:~$ ls
Desktop  Downloads  id_rsa.pub  Pictures  Templates
Documents examples.desktop  Music  Public  Videos
justin@justin-VirtualBox:~$ touch ~/.ssh/authorized_keys
justin@justin-VirtualBox:~$ chmod 644 ~/.ssh/authorized_keys
justin@justin-VirtualBox:~$ cat id_rsa.pub > ~/.ssh/authorized_keys
justin@justin-VirtualBox:~$ cat ~/.ssh/authorized_keys
ssh-rsa AAAAB3NzaC1yc2EAAQABAAQAC2Y5fkJVVRldub8+ayMfdkOBc9arnGm721AtDV
Ma2197VccFFIiRPTbhXqNEt9408FHA33zsZ+VM0itfWJ7Acqhojk21/pIlerHe6K7LqdxdVdg3sv/
g/Rhythmbox ZWYsgueynqceUpyx1tPtoVK8q1wsWE56gtWoa+yPmUXewTD02DUJLuvdEvBn2
qcf2Qo+ViRQEtbTxp2fvkvAEijznWmhTpUyU90PztIxDeZRFW1SpzsAs4PaermvxymLPr9Xt6
oPxZLfo+NboYtwZovleDxg0zU09X5+QMLAIoDnj+uG6k//wf3jq4JLgwnaVvA justin@justin-
VirtualBox2
justin@justin-VirtualBox:~$
```

I. Login to vm1 from vm2, using the specified private key

vm2 [Running] - Oracle VM VirtualBox

File Machine View Input Devices Help

Activities Terminal Tue 16:51

justin@justin-VirtualBox: ~

```
File Edit View Search Terminal Help
justin@justin-VirtualBox2:~$ ssh-copy-id justin@10.0.2.4
/usr/bin/ssh-copy-id: INFO: attempting to log in with the new key(s), to filter
out any that are already installed
/usr/bin/ssh-copy-id: INFO: 2 key(s) remain to be installed -- if you are prompted now it is to install the new keys
justin@10.0.2.4's password:

Number of key(s) added: 2

Now try logging into the machine, with: "ssh 'justin@10.0.2.4'"
and check to make sure that only the key(s) you wanted were added.

justin@justin-VirtualBox2:~$ ssh -i ~/.ssh/id_rsa justin@10.0.2.4
Welcome to Ubuntu 18.04.3 LTS (GNU/Linux 4.15.0-58-generic x86_64)

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

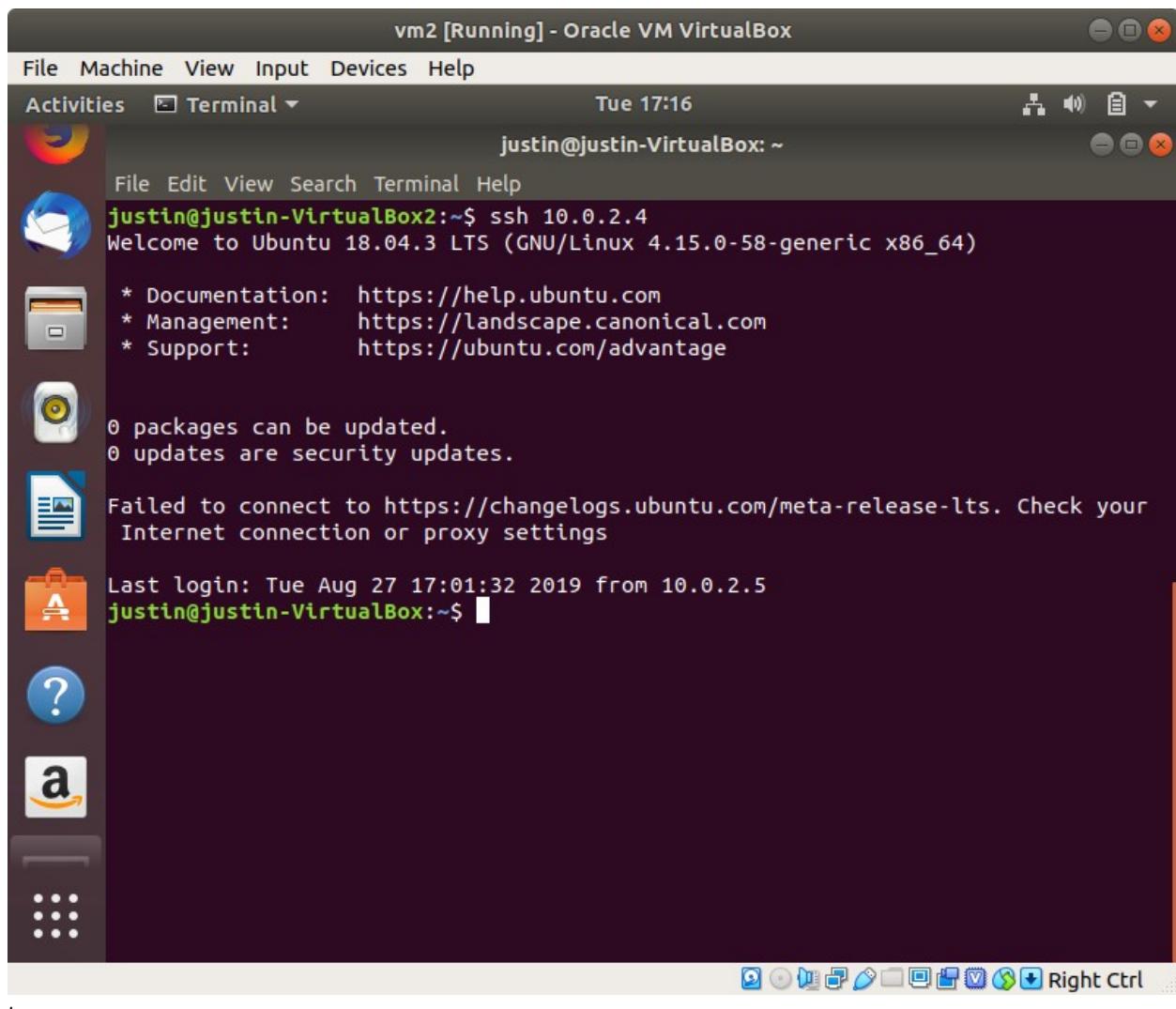
0 packages can be updated.
0 updates are security updates.

Failed to connect to https://changelogs.ubuntu.com/meta-release-lts. Check your
Internet connection or proxy settings

Last login: Tue Aug 27 16:49:56 2019 from 10.0.2.5
justin@justin-VirtualBox:~$
```

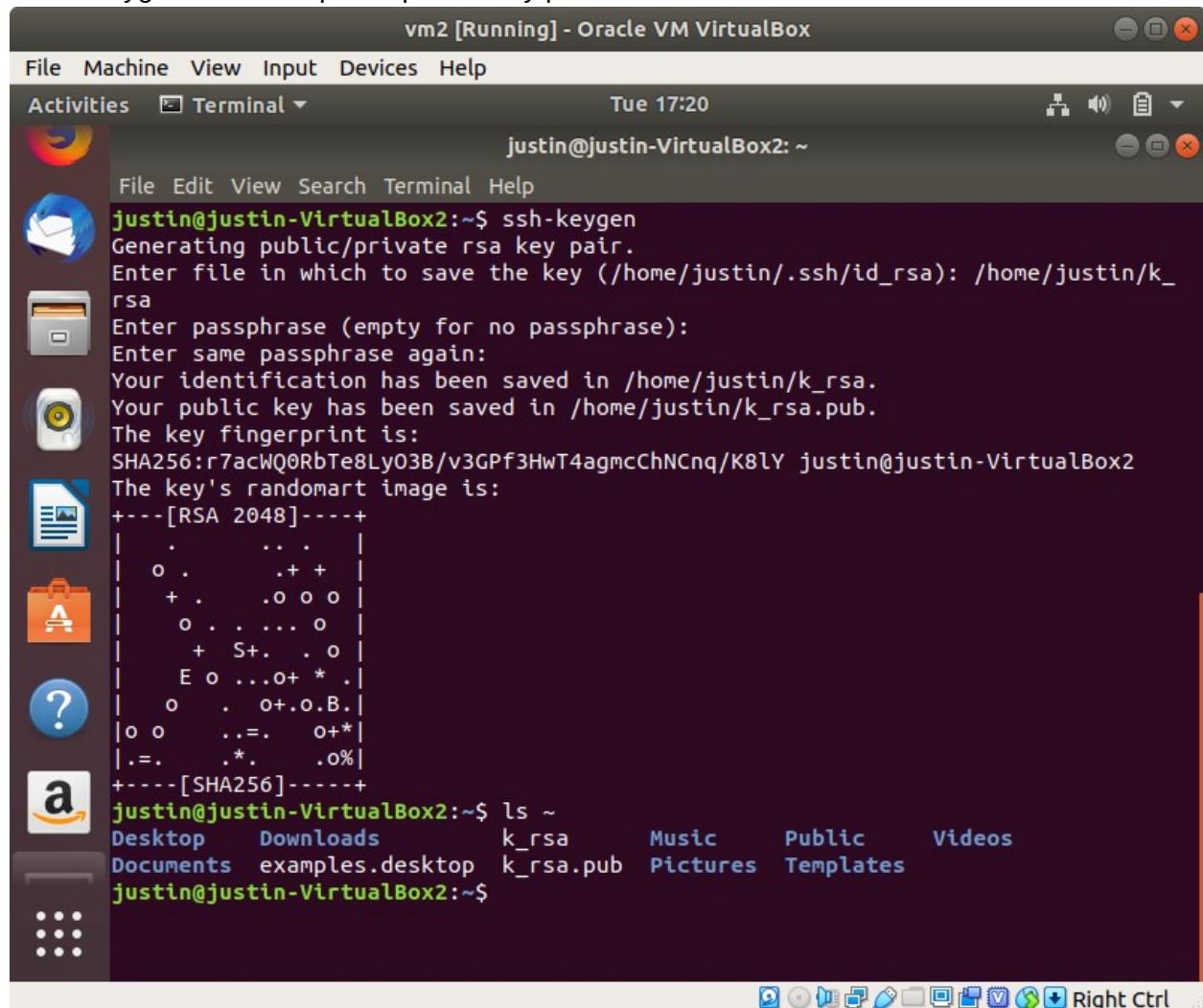
Q2

- a. ssh - Connect to a remote host using the ssh protocol



t

b. ssh-keygen - create a public-private key pair for ssh authentication



The screenshot shows a Linux desktop environment with a terminal window open in a window titled "vm2 [Running] - Oracle VM VirtualBox". The terminal window has a dark background and displays the following command and its output:

```
justin@justin-VirtualBox2:~$ ssh-keygen
Generating public/private rsa key pair.
Enter file in which to save the key (/home/justin/.ssh/id_rsa): /home/justin/k_
rsa
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /home/justin/k_rsa.
Your public key has been saved in /home/justin/k_rsa.pub.
The key fingerprint is:
SHA256:r7acWQ0RbTe8Ly03B/v3GPf3HwT4agmcChNCnq/K8lY justin@justin-VirtualBox2
The key's randomart image is:
+---[RSA 2048]----+
| .   ... |
| o .   .+ + |
| + .   .o o o |
| o . . . . o |
| + S+.. . o |
| E o ...o+ * .|
| o   . o+.o.B.|
| o o   ... o+* |
| .=.   .* .o% |
+---[SHA256]----+
justin@justin-VirtualBox2:~$ ls ~
Desktop  Downloads  k_rsa      Music      Public    Videos
Documents examples.desktop k_rsa.pub  Pictures  Templates
justin@justin-VirtualBox2:~$
```

c. scp - copy files from remote to local, and vice versa

```
vm2 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Activities Terminal Tue 17:22
justin@justin-VirtualBox: ~
File Edit View Search Terminal Help
justin@justin-VirtualBox2:~$ echo "from vm2" > note.txt
justin@justin-VirtualBox2:~$ cat note.txt
from vm2
justin@justin-VirtualBox2:~$ scp /home/justin/note.txt justin@10.0.2.4:note.txt
note.txt                                100%    9      5.1KB/s   00:00
justin@justin-VirtualBox2:~$ ssh justin@10.0.2.4
Welcome to Ubuntu 18.04.3 LTS (GNU/Linux 4.15.0-58-generic x86_64)

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

0 packages can be updated.
0 updates are security updates.

Failed to connect to https://changelogs.ubuntu.com/meta-release-lts. Check your
Internet connection or proxy settings

Last login: Tue Aug 27 17:16:20 2019 from 10.0.2.5
justin@justin-VirtualBox:~$ ls
Desktop  Downloads  id_rsa.pub  note.txt  Public  Videos
Documents examples.desktop  Music  Pictures  Templates
justin@justin-VirtualBox:~$ cat note.txt
from vm2
justin@justin-VirtualBox:~$
```

d. history - display previously inputted commands

```
148 clear
149 ssh-keygen
150 clear
151 ssh-keygen
152 clear
153 ssh-keygen
154 ls -l ~/
155 clear
156 ssh-keygen
157 clear
158 rm ~/id_rsa
159 rm ~/id_rsa.pub
160 clear
161 ssh-keygen
162 clear
163 ssh-keygen
164 ls ~
165 clear
Help rm k_rsa*
167 ls
168 clear
169 echo "from vm2" > note.txt
170 cat note.txt
171 scp /home/justin/note.txt justin@10.0.2.4:note.txt
172 ssh justin@10.0.2.4
173 clear
174 history
justin@justin-VirtualBox2:~$
```

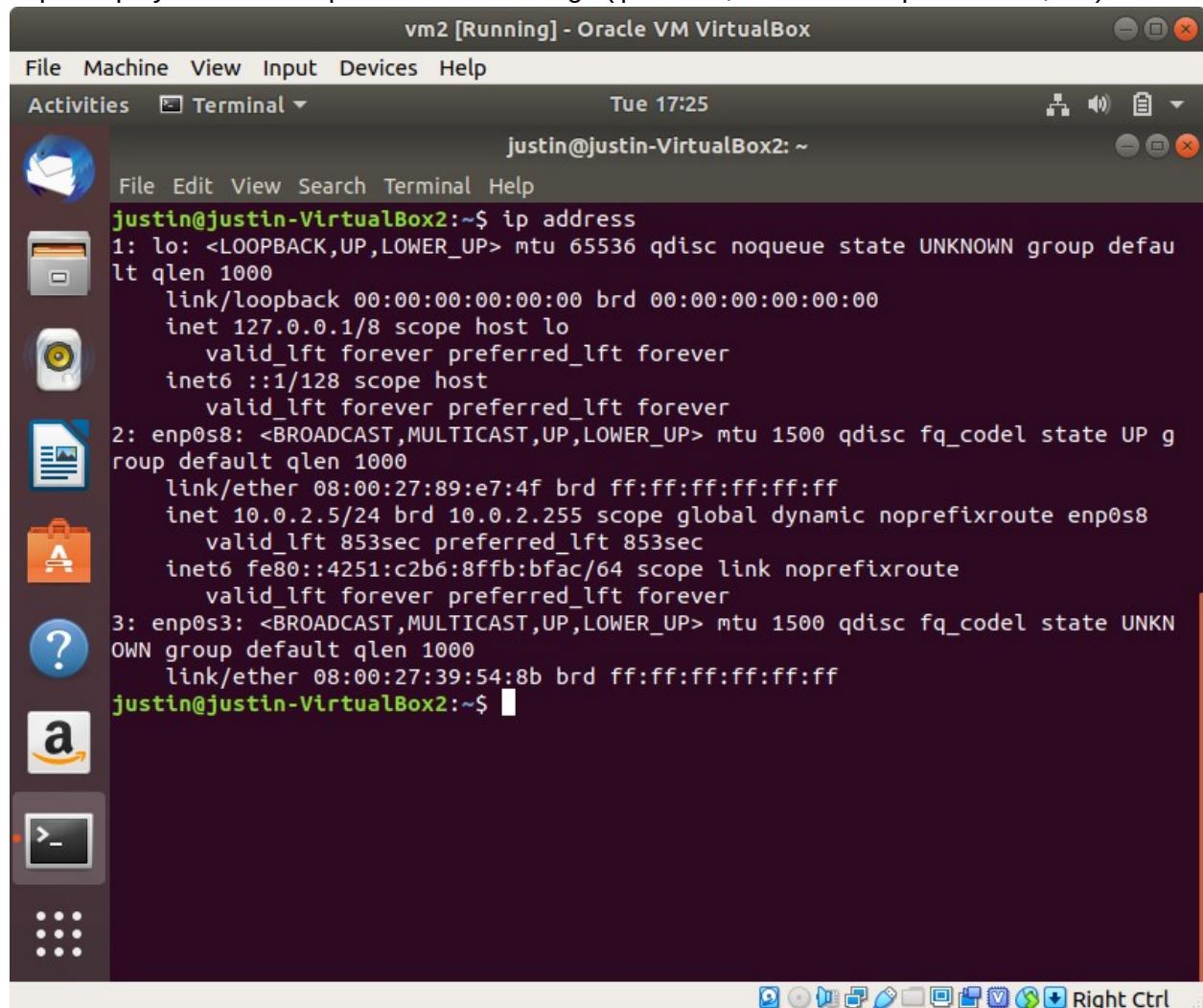
e. sudo - Execute commands at elevated privilege user

The screenshot shows a Linux desktop environment with a terminal window open. The terminal window title is "vm2 [Running] - Oracle VM VirtualBox". The terminal content shows the user "justin" attempting to run the "ufw status" command without sudo, receiving an error message about needing root privileges. Then, the user runs "sudo ufw status" and is prompted for a password. The output shows the status as active with two rules allowing traffic on port 22/tcp from anywhere.

```
justin@justin-VirtualBox2:~$ ufw status
ERROR: You need to be root to run this script
justin@justin-VirtualBox2:~$ sudo ufw status
[sudo] password for justin:
Status: active

To                         Action      From
--                         --          --
22/tcp                     ALLOW      Anywhere
22/tcp (v6)                ALLOW      Anywhere (v6)
```

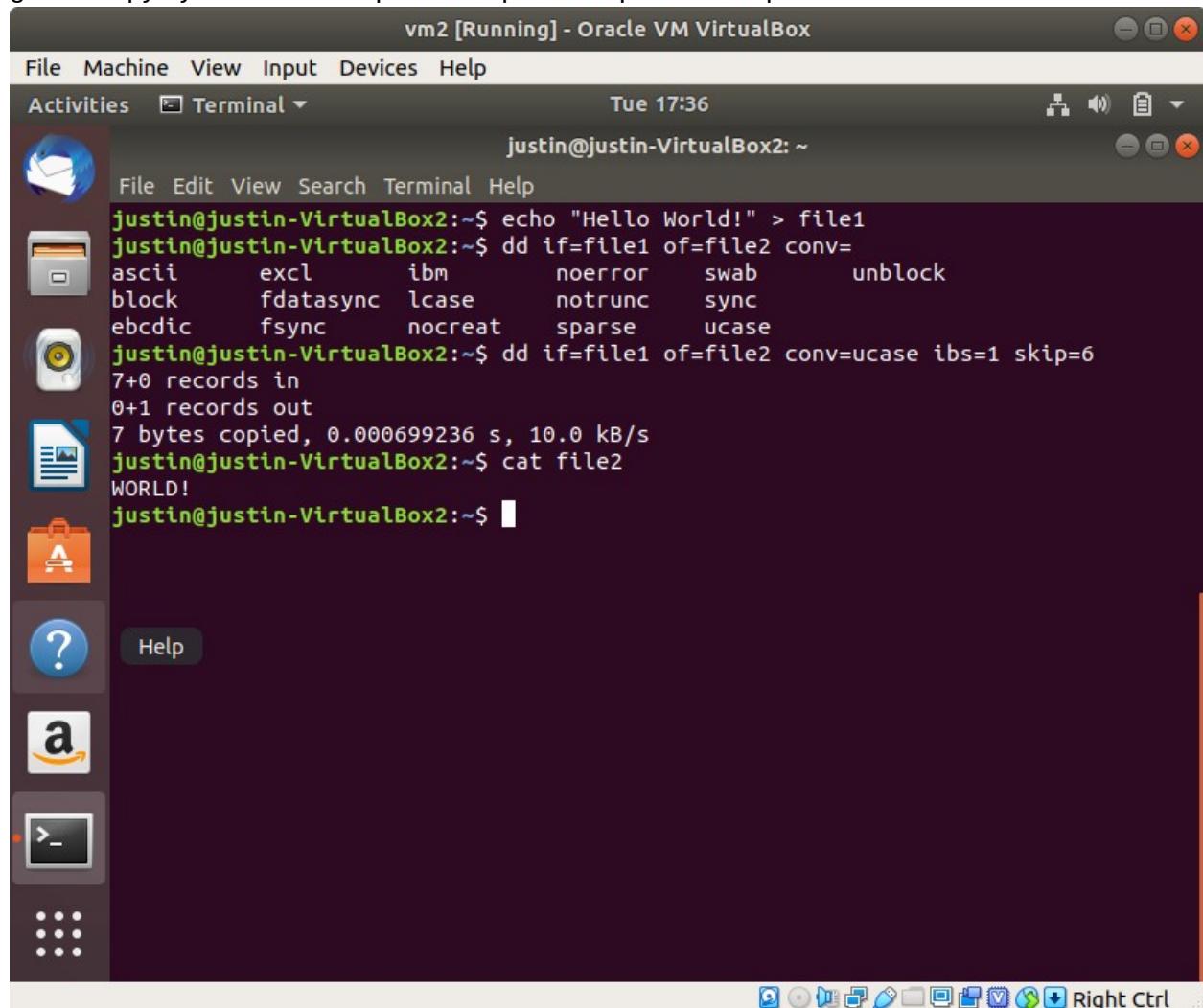
f. ip - display network adapter interface settings (ip masks, addresses - ip and MAC, etc)



The image shows a screenshot of an Ubuntu desktop environment running inside Oracle VM VirtualBox. The terminal window is titled "vm2 [Running] - Oracle VM VirtualBox". The terminal session shows the command "ip address" being run, displaying network interface configurations for "lo", "enp0s8", and "enp0s3".

```
justin@justin-VirtualBox2:~$ ip address
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: enp0s8: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel state UP group default qlen 1000
    link/ether 08:00:27:89:e7:4f brd ff:ff:ff:ff:ff:ff
    inet 10.0.2.5/24 brd 10.0.2.255 scope global dynamic noprefixroute enp0s8
        valid_lft 853sec preferred_lft 853sec
    inet6 fe80::4251:c2b6:8ffb:bfac/64 scope link noprefixroute
        valid_lft forever preferred_lft forever
3: enp0s3: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel state UNKNOWN group default qlen 1000
    link/ether 08:00:27:39:54:8b brd ff:ff:ff:ff:ff:ff
justin@justin-VirtualBox2:~$
```

g. dd - copy bytes files from specified input to output. Shows performance.



The screenshot shows a Linux desktop environment with a terminal window open in a window titled "vm2 [Running] - Oracle VM VirtualBox". The terminal window has a dark background and displays the following command-line session:

```
justin@justin-VirtualBox2:~$ echo "Hello World!" > file1
justin@justin-VirtualBox2:~$ dd if=file1 of=file2 conv=
    ascii    excl    ibm    noerror    swab    unblock
    block    fdatasync    lcase    notrunc    sync
    ebdic    fsync    nocreat    sparse    ucase
justin@justin-VirtualBox2:~$ dd if=file1 of=file2 conv=ucase ibs=1 skip=6
7+0 records in
0+1 records out
7 bytes copied, 0.000699236 s, 10.0 kB/s
justin@justin-VirtualBox2:~$ cat file2
WORLD!
justin@justin-VirtualBox2:~$
```

The terminal window includes a menu bar with File, Machine, View, Input, Devices, Help, and Activities. The Activities button is highlighted. The status bar shows the date and time as "Tue 17:36". The desktop interface features a dock on the left with icons for Mail, Files, Terminal, Help, Amazon, and a terminal icon. A toolbar at the bottom contains icons for various applications like a browser, file manager, and system tools. The desktop background is a solid dark color.

h. fdisk - Manage the partition of a disk device

The screenshot shows a Linux desktop environment with a terminal window open. The terminal window title is "vm2 [Running] - Oracle VM VirtualBox". The terminal command "justin@justin-VirtualBox2:~\$ sudo fdisk /dev/sda" is run, followed by the fdisk utility's welcome message and disk information. The terminal then displays the current partition table for /dev/sda, which contains one partition (/dev/sda1) of type 83 (Linux). The terminal prompt "justin@justin-VirtualBox2:~\$ " is visible at the bottom.

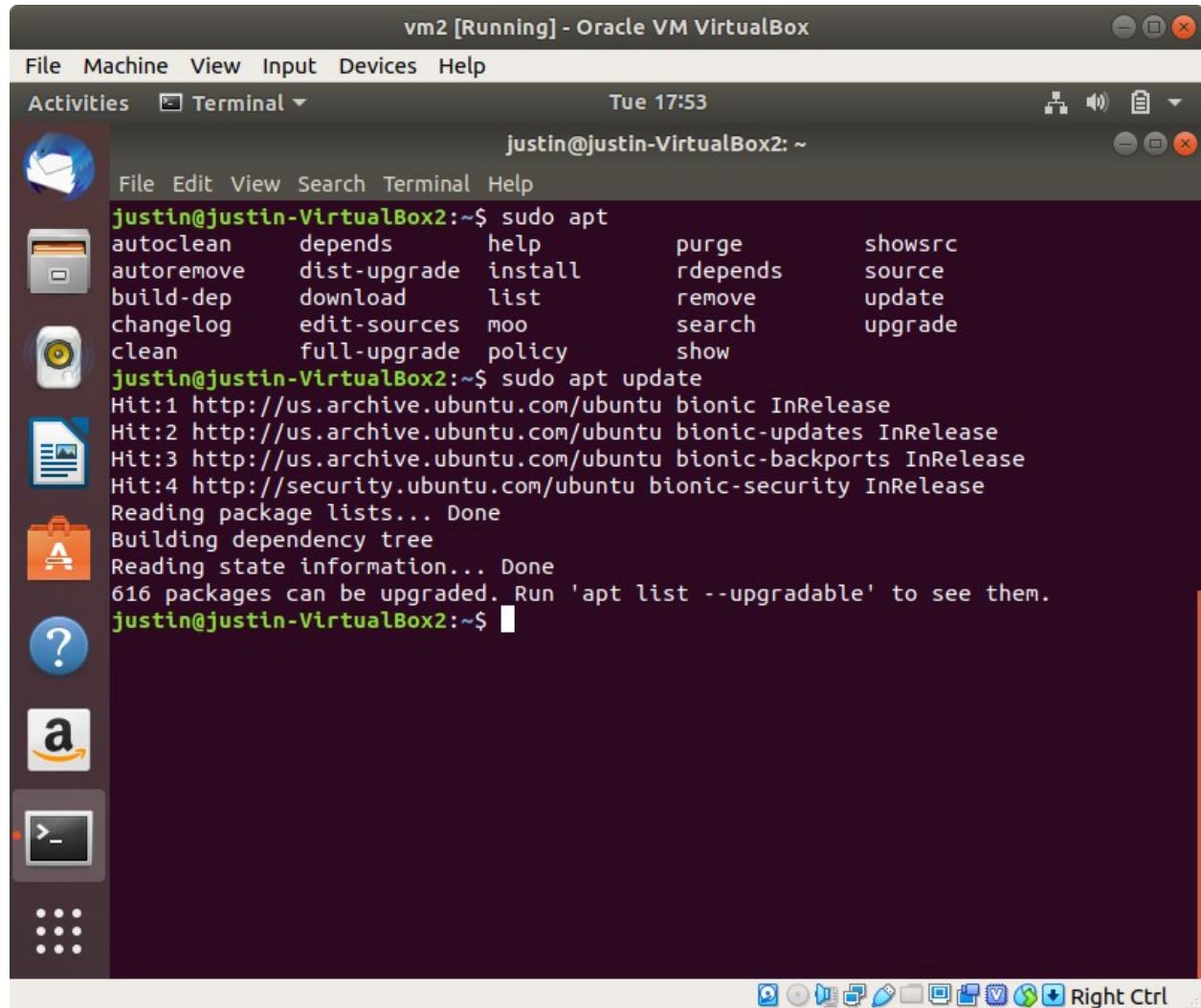
```
justin@justin-VirtualBox2:~$ sudo fdisk /dev/sda
Welcome to fdisk (util-linux 2.31.1).
Changes will remain in memory only, until you decide to write them.
Be careful before using the write command.

Command (m for help): p
Disk /dev/sda: 25 GiB, 26843545600 bytes, 52428800 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 identifier: 0x935b26e1

Device      Boot Start     End Sectors Size Id Type
/dev/sda1    *     2048 52426751 52424704 25G 83 Linux

Command (m for help): q
justin@justin-VirtualBox2:~$
```

i. apt - the command line interface for the package manager in ubuntu. Use to install and remove packages.



The screenshot shows a Linux desktop environment with a terminal window open. The terminal window title is "vm2 [Running] - Oracle VM VirtualBox". The terminal content shows the user running apt commands:

```
justin@justin-VirtualBox2:~$ sudo apt
auto-clean depends help purge showsrc
autoremove dist-upgrade install rdepends source
build-dep download list remove update
changelog edit-sources moo search upgrade
clean full-upgrade policy show
justin@justin-VirtualBox2:~$ sudo apt update
Hit:1 http://us.archive.ubuntu.com/ubuntu bionic InRelease
Hit:2 http://us.archive.ubuntu.com/ubuntu bionic-updates InRelease
Hit:3 http://us.archive.ubuntu.com/ubuntu bionic-backports InRelease
Hit:4 http://security.ubuntu.com/ubuntu bionic-security InRelease
Reading package lists... Done
Building dependency tree
Reading state information... Done
616 packages can be upgraded. Run 'apt list --upgradable' to see them.
justin@justin-VirtualBox2:~$
```

The desktop environment includes a dock with various icons (file manager, terminal, browser, etc.) and a system tray at the bottom.

j. vi - lightweight text editor

The screenshot shows a Linux desktop environment with a dark theme. At the top, there's a menu bar with "File", "Machine", "View", "Input", "Devices", and "Help". Below the menu is a docked application bar with icons for "Activities", "Terminal", and other system status indicators like battery and signal strength. The main window is a terminal session titled "vm2 [Running] - Oracle VM VirtualBox". The terminal window has a title bar with "File", "Edit", "View", "Search", "Terminal", and "Help". The command line shows the user has run "from vm2" and "hello world!". The desktop background is a solid dark color, and the overall interface is clean and modern.

The screenshot shows a Linux desktop environment within a virtual machine. The desktop is a dark blue color. On the left, there's a vertical dock with several icons: a mail icon, a folder icon, a system tray icon, a file icon, a folder with an 'A' icon, a question mark icon, an 'a' icon, and a terminal icon. The main window title is "vm2 [Running] - Oracle VM VirtualBox". The menu bar includes "File", "Machine", "View", "Input", "Devices", and "Help". Below the menu is a "Activities" button and a "Terminal" dropdown. The date and time "Tue 17:59" are displayed. The terminal window has a title "justin@justin-VirtualBox2: ~" and a menu bar with "File", "Edit", "View", "Search", "Terminal", and "Help". It shows the command "vi note.txt" run, followed by "cat note.txt" and its output "from vm2" and "hello world!". The bottom of the screen features a dock with various application icons.

k. time - show the execution time of a program

The screenshot shows a Linux desktop environment with a dark theme. A terminal window titled "vm2 [Running] - Oracle VM VirtualBox" is open, displaying the following command-line session:

```
justin@justin-VirtualBox2:~$ cat hello.py
#!/usr/bin/env python3

print('hello world!')
justin@justin-VirtualBox2:~$ chmod a+x hello.py
justin@justin-VirtualBox2:~$ ls -l hello.py
-rwxr-xr-x 1 justin justin 46 Aug 27 18:03 hello.py
justin@justin-VirtualBox2:~$ time ./hello.py
hello world!

real    0m0.056s
user    0m0.046s
sys     0m0.009s
justin@justin-VirtualBox2:~$
```

The desktop interface includes a docked application menu on the left with icons for Mail, Files, Terminal, Help, and others. A "Show Applications" button is visible at the bottom of the dock. The bottom bar features a row of icons for various system functions like network, file manager, and system settings.

I. tar - archive and compress files and directories, and also extracts created archives

```
File Edit View Search Terminal Help
justin@justin-VirtualBox2:~$ ls dir1
file1 file2 hello.py note.txt
justin@justin-VirtualBox2:~$ tar cf archive1.tar dir1
justin@justin-VirtualBox2:~$ ls
archive1.tar dir1 Downloads Music Public Videos
Desktop Documents examples.desktop Pictures Templates
justin@justin-VirtualBox2:~$ rm -r dir1
justin@justin-VirtualBox2:~$ ls
archive1.tar Documents examples.desktop Pictures Templates
Desktop Downloads Music Public Videos
justin@justin-VirtualBox2:~$ tar xf archive1.tar
justin@justin-VirtualBox2:~$ ls
archive1.tar dir1 Downloads Music Public Videos
Desktop Documents examples.desktop Pictures Templates
justin@justin-VirtualBox2:~$
```

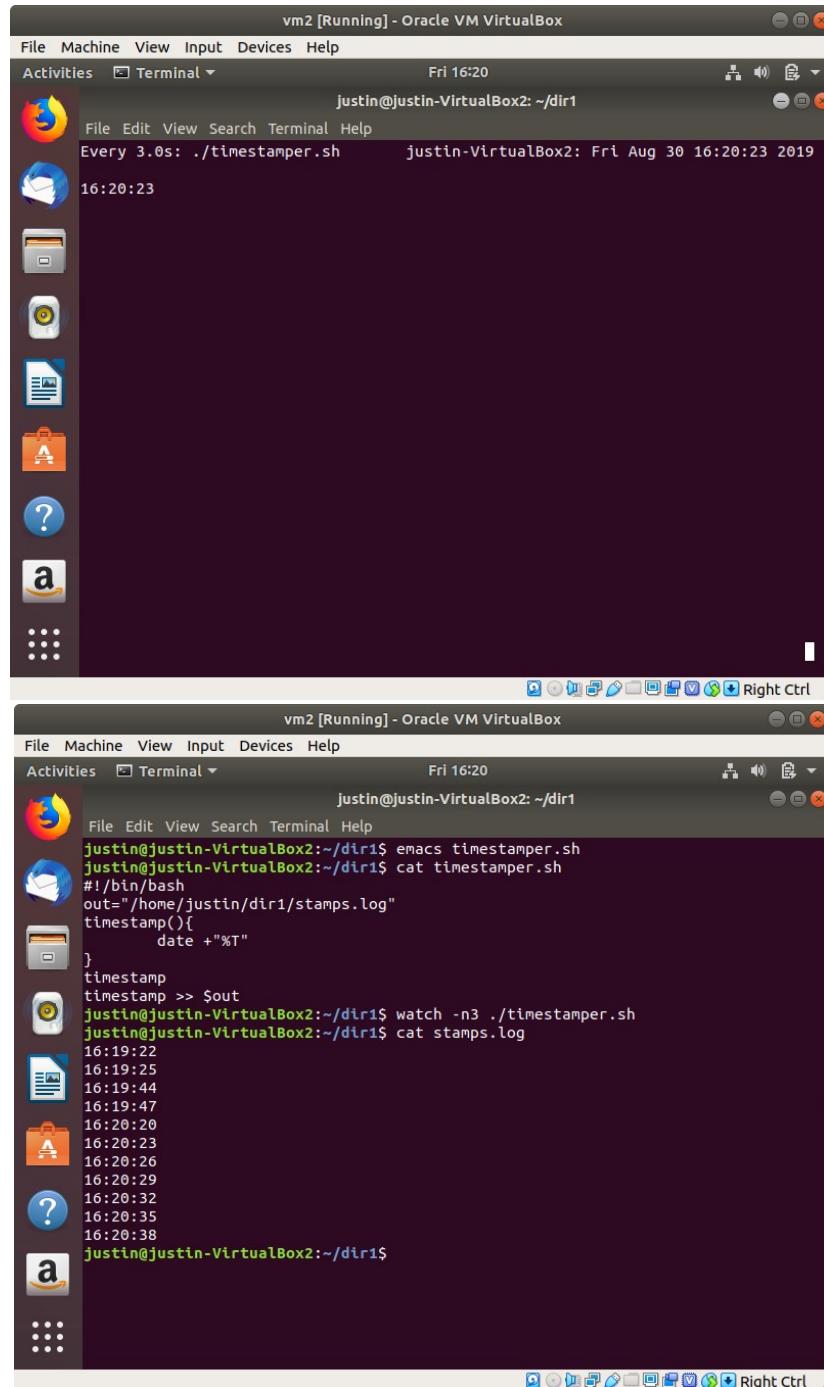
m. cat - print contents of file to standard output

The screenshot shows a Linux desktop environment with a terminal window open in a virtual machine named "vm2 [Running]". The terminal window title is "vm2 [Running] - Oracle VM VirtualBox". The desktop interface includes a docked panel on the left containing icons for various applications like Mail, Files, Terminal, Activities, Dash, Help, and a search bar. The terminal window displays the following command-line session:

```
justin@justin-VirtualBox2:~$ cat ~/dir1/
file1    file2    hello.py  note.txt
justin@justin-VirtualBox2:~$ cat ~/dir1/
file1    file2    hello.py  note.txt
justin@justin-VirtualBox2:~$ cat ~/dir1/
file1    file2    hello.py  note.txt
justin@justin-VirtualBox2:~$ cat ~/dir1/hello.py
#!/usr/bin/env python3
print('hello world!')
justin@justin-VirtualBox2:~$
```

The terminal window also shows the date and time as "Tue 18:15" at the top right.

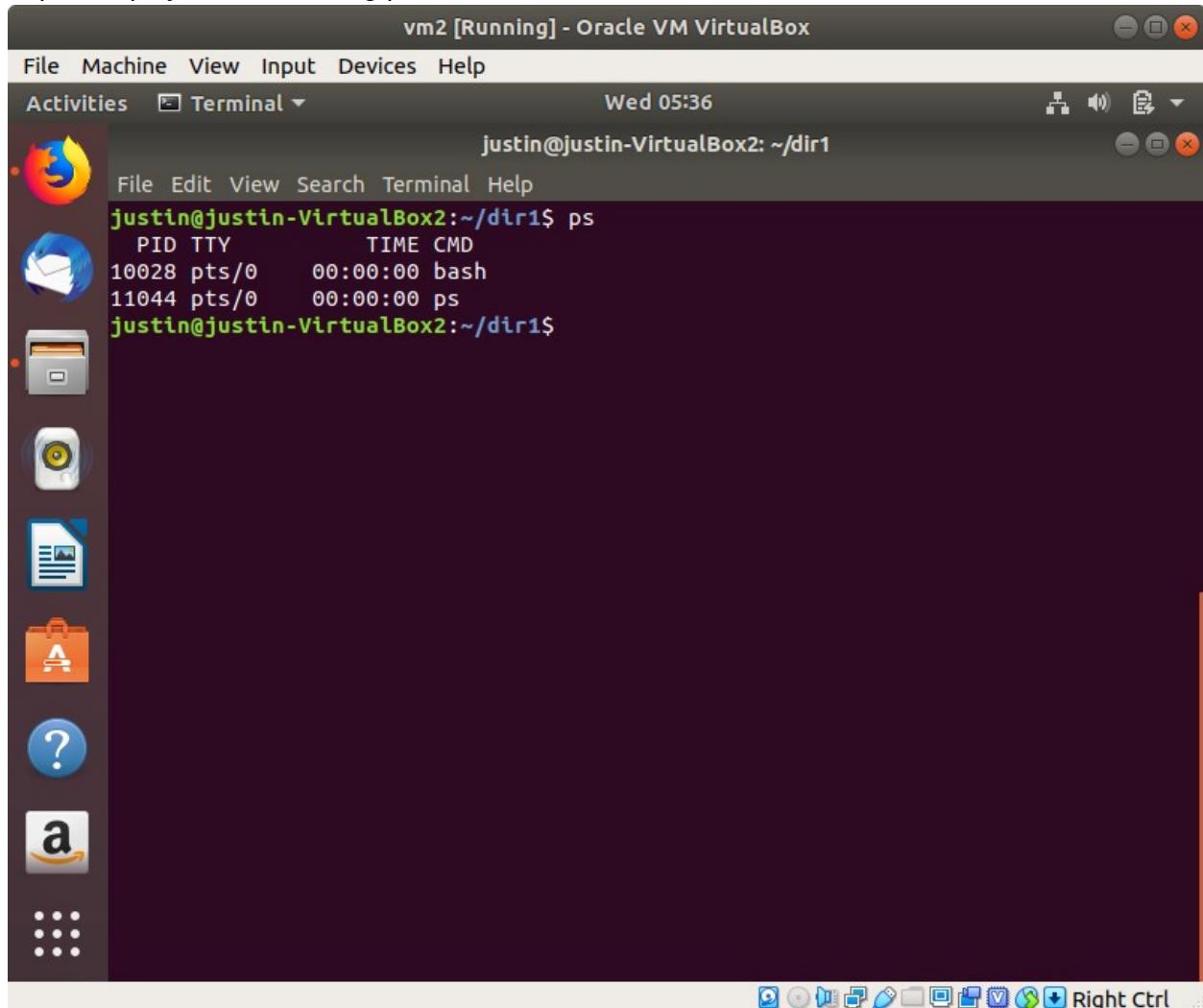
n. watch - periodically execute a command in the shell, while displaying the output on every execution.



The image shows a Linux desktop environment with two terminal windows running on an Oracle VM VirtualBox machine. The desktop has a dark theme with a vertical dock on the left containing icons for various applications like a browser, file manager, terminal, and system settings. The top window is titled "vm2 [Running] - Oracle VM VirtualBox" and shows the command "Every 3.0s: ./timestamper.sh" being run. The output in the terminal shows the current date and time (Fri Aug 30 16:20:23 2019) followed by the timestamp from the script. The bottom window is also titled "vm2 [Running] - Oracle VM VirtualBox" and shows the user navigating to a directory (~/.dir1), running "emacs timestamper.sh" to edit the script, and then running "watch -n3 ./timestamper.sh" to start the periodic execution. The output shows the timestamps from the script being printed at 3-second intervals: 16:19:22, 16:19:25, 16:19:44, 16:19:47, 16:20:20, 16:20:23, 16:20:26, 16:20:29, 16:20:32, 16:20:35, and 16:20:38.

```
Every 3.0s: ./timestamper.sh      justin@justin-VirtualBox2: Fri Aug 30 16:20:23 2019  
16:20:23  
  
justin@justin-VirtualBox2:~/dir1$ emacs timestamper.sh  
#!/bin/bash  
out="/home/justin/dir1/stamps.log"  
timestamp(){  
    date +"%T"  
}  
timestamp  
timestamp >> $out  
justin@justin-VirtualBox2:~/dir1$ watch -n3 ./timestamper.sh  
justin@justin-VirtualBox2:~/dir1$ cat stamps.log  
16:19:22  
16:19:25  
16:19:44  
16:19:47  
16:20:20  
16:20:23  
16:20:26  
16:20:29  
16:20:32  
16:20:35  
16:20:38
```

o. ps - display current running processes



p. top - Display all running linux processes, dynamically

The screenshot shows a Linux desktop environment with a terminal window open. The terminal window title is "vm2 [Running] - Oracle VM VirtualBox". The terminal command "top" is running, displaying system statistics and a list of processes. The desktop interface includes a dock at the bottom with various icons.

```
justin@justin-VirtualBox2: ~/dir1
top - 05:37:00 up 2:31, 1 user, load average: 0.09, 0.17, 0.18
Tasks: 178 total, 1 running, 141 sleeping, 0 stopped, 0 zombie
%Cpu(s): 1.7 us, 0.2 sy, 0.0 ni, 98.0 id, 0.0 hi, 0.2 si, 0.0 st
KiB Mem : 4039564 total, 694724 free, 1168660 used, 2176180 buff/cache
KiB Swap: 1214880 total, 1214880 free, 0 used. 2747400 avail Mem

PID USER PR NI VIRT RES SHR S %CPU %MEM TIME+ COMMAND
1072 justin 20 0 3454420 252196 95192 S 3.0 6.2 4:54.45 gnome-she+
11048 justin 20 0 51188 4040 3408 R 1.0 0.1 0:00.05 top
868 justin 20 0 534804 73176 40904 S 0.3 1.8 1:30.32 Xorg
5416 root 20 0 0 0 0 I 0.3 0.0 0:03.25 kworker/0+
10328 justin 20 0 2546268 308832 136360 S 0.3 7.6 0:30.66 firefox
1 root 20 0 225536 9288 6692 S 0.0 0.2 0:02.54 systemd
2 root 20 0 0 0 0 S 0.0 0.0 0:00.00 kthreadd
4 root 0 -20 0 0 0 I 0.0 0.0 0:00.00 kworker/0+
6 root 0 -20 0 0 0 I 0.0 0.0 0:00.00 mm_percpu+
7 root 20 0 0 0 0 S 0.0 0.0 0:00.48 ksoftirqd+
8 root 20 0 0 0 0 I 0.0 0.0 0:02.04 rcu_sched
9 root 20 0 0 0 0 I 0.0 0.0 0:00.00 rcu_bh
10 root rt 0 0 0 0 S 0.0 0.0 0:00.00 migration+
11 root rt 0 0 0 0 S 0.0 0.0 0:00.06 watchdog/0
12 root 20 0 0 0 0 S 0.0 0.0 0:00.00 cpuhp/0
13 root 20 0 0 0 0 S 0.0 0.0 0:00.00 cpuhp/1
14 root rt 0 0 0 0 S 0.0 0.0 0:00.05 watchdog/1
15 root rt 0 0 0 0 S 0.0 0.0 0:00.00 migration+
16 root 20 0 0 0 0 S 0.0 0.0 0:00.37 ksoftirqd+
18 root 0 -20 0 0 0 I 0.0 0.0 0:00.00 kworker/1+
19 root 20 0 0 0 0 S 0.0 0.0 0:00.00 kdevtmpfs
```

q. htop - A “prettier” top, with more functionalities (e.g. select multiple processes at once)

The screenshot shows a terminal window titled "vm2 [Running] - Oracle VM VirtualBox". The window title bar includes standard icons for minimize, maximize, and close. Below the title bar is a menu bar with "File", "Machine", "View", "Input", "Devices", and "Help". A tab bar shows "Activities" and "Terminal". The main area displays system monitoring information and a process list.

System status indicators:

- Tasks: 110, 359 thr; 1 running
- Load average: 0.12 0.17 0.18
- Uptime: 02:32:53

Memory usage:

Mem	1.14G/3.85G
Swp	0K/1.16G

Process list (PID, USER, PRI, NI, VIRT, RES, SHR, S, CPU%, MEM%, TIME+, Command):

PID	USER	PRI	NI	VIRT	RES	SHR	S	CPU%	MEM%	TIME+	Command
1072	justin	20	0	3383M	246M	95192	S	1.3	6.3	4:57.99	/usr/bin/gnome-s
11696	justin	20	0	40760	4904	3924	R	0.7	0.1	0:00.37	htop
868	justin	20	0	522M	73176	40904	S	0.7	1.8	1:31.21	/usr/lib/xorg/Xo
1084	justin	20	0	3383M	246M	95192	S	0.0	6.3	0:15.43	/usr/bin/gnome-s
1085	justin	20	0	3383M	246M	95192	S	0.0	6.3	0:17.37	/usr/bin/gnome-s
10018	justin	20	0	786M	39736	28740	S	0.0	1.0	0:05.83	/usr/lib/gnome-t
1	root	20	0	220M	9288	6692	S	0.0	0.2	0:02.55	/sbin/init splas
10328	justin	20	0	2486M	301M	133M	S	0.0	7.6	0:30.81	/usr/lib/firefox
929	justin	20	0	522M	73176	40904	S	0.0	1.8	0:03.73	/usr/lib/xorg/Xo
652	root	20	0	70584	6048	5276	S	0.0	0.1	0:00.37	/lib/systemd/sys
1102	justin	20	0	368M	10200	8292	S	0.0	0.3	0:24.72	ibus-daemon --xi
1104	justin	20	0	368M	10200	8292	S	0.0	0.3	0:17.09	ibus-daemon --xi
10773	justin	20	0	2486M	301M	133M	S	0.0	7.6	0:00.00	/usr/lib/firefox
10756	justin	20	0	2486M	301M	133M	S	0.0	7.6	0:00.00	/usr/lib/firefox
10732	justin	20	0	2486M	301M	133M	S	0.0	7.6	0:00.00	/usr/lib/firefox
10731	justin	20	0	1575M	86060	65920	S	0.0	2.1	0:00.17	/usr/lib/firefox
10755	justin	20	0	1575M	86060	65920	S	0.0	2.1	0:00.00	/usr/lib/firefox
10754	justin	20	0	1575M	86060	65920	S	0.0	2.1	0:00.00	/usr/lib/firefox
10753	justin	20	0	1575M	86060	65920	S	0.0	2.1	0:00.00	/usr/lib/firefox
10752	justin	20	0	1575M	86060	65920	S	0.0	2.1	0:00.00	/usr/lib/firefox

Bottom status bar:

F1 Help F2 Setup F3 Search F4 Filter F5 Tree F6 SortBy F7 Nice - F8 Nice + F9 Kill F10 Quit Right Ctrl

r. gcc - GNU C compiler

vm2 [Running] - Oracle VM VirtualBox

File Machine View Input Devices Help

Activities Terminal ▾

Wed 05:43

justin@justin-VirtualBox2: ~/dir1

File Edit View Search Terminal Help

```
justin@justin-VirtualBox2:~/dir1$ cat hello.c
#include <stdio.h>
int main(){
    printf("Hello World!\n");
    return 0;
}

justin@justin-VirtualBox2:~/dir1$ gcc -Wall -o hello hello.c
justin@justin-VirtualBox2:~/dir1$ ./hello
Hello World!
justin@justin-VirtualBox2:~/dir1$
```

The screenshot shows a Linux desktop environment, likely Ubuntu, running inside a VirtualBox virtual machine. The desktop has a dark theme with a dock at the bottom containing icons for various applications like Dash, Home, Applications, Help, and Amazon. A terminal window is open in the center, showing the user's command-line session. The user typed 'cat hello.c' to view the source code, which contains a simple 'Hello World!' program. Then, they compiled it with 'gcc -Wall -o hello hello.c' and ran it with './hello', producing the expected output. The desktop also features a dock at the bottom with icons for Dash, Home, Applications, Help, and Amazon.

s. tail - print the last lines of a file to stdout

The screenshot shows a Linux desktop environment with a dark theme. A terminal window titled "vm1 [Running] - Oracle VM VirtualBox" is open, displaying the command "tail happy_free_market_log.txt". The terminal output includes:

```
justin@justin-VirtualBox:~$ tail happy_free_market_log.txt
thankyoucomeagain
Timestamp 17675901
  Files
A purchase! COIN ALGORITHM FAILED This is not purchase. This is another forged
Neocredit trick.

The hot summer sun
Sears hunger into your throat;
Eat a bag of dirt.
justin@justin-VirtualBox:~$
```

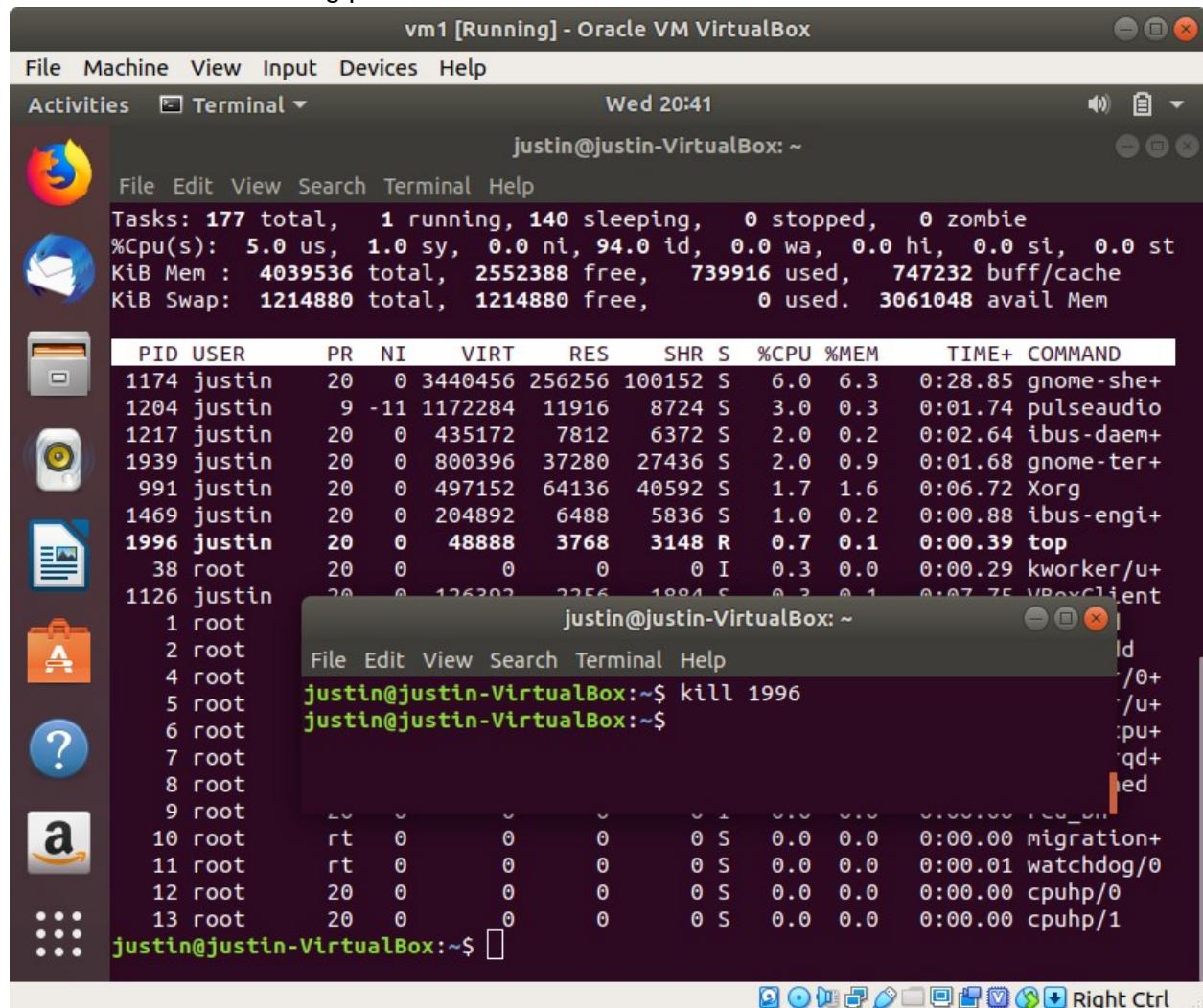
The desktop interface features a dock at the bottom with various icons, including a file manager, a browser, and system tools. A vertical dock on the left contains icons for a file browser, terminal, applications, help, and a search function.

t. grep - a text filter program that finds matches from input files using regex.

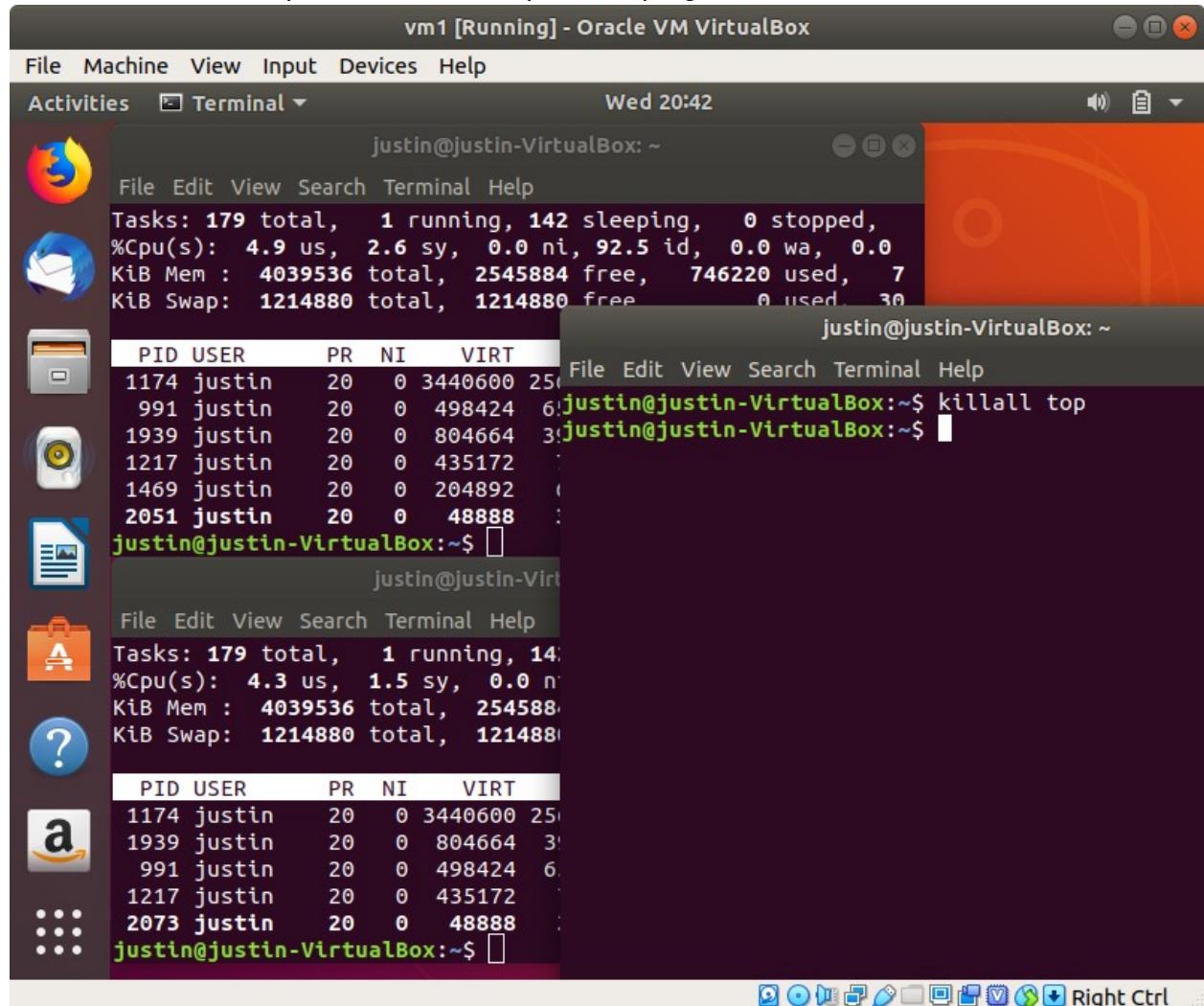
The screenshot shows a Linux desktop environment with a dark theme. A terminal window titled "vm1 [Running] - Oracle VM VirtualBox" is open, displaying the output of a grep command. The terminal window includes a menu bar with "File", "Machine", "View", "Input", "Devices", and "Help". Below the menu is an "Activities" button and a "Terminal" button. The status bar shows the date and time as "Wed 20:37" and the user as "justin@justin-VirtualBox: ~". The terminal itself has a scrollback buffer containing multiple lines of timestamped log entries. The desktop background features a grid of application icons on the left side of the screen.

```
justin@justin-VirtualBox:~$ cat happy_free_market_log.txt | grep '[tT]imestamp'
Timestamp 17643390
Timestamp 17646520
Timestamp 17648990
Timestamp 17649001
Timestamp 17649136
Timestamp 17649259
Timestamp 17649385
Timestamp 17649511
Timestamp 17649639
Timestamp 17656901
Timestamp 17657230
Timestamp 17659861
Timestamp 17659873
Timestamp 17659999
Timestamp 17675799
Timestamp 17675901
justin@justin-VirtualBox:~$
```

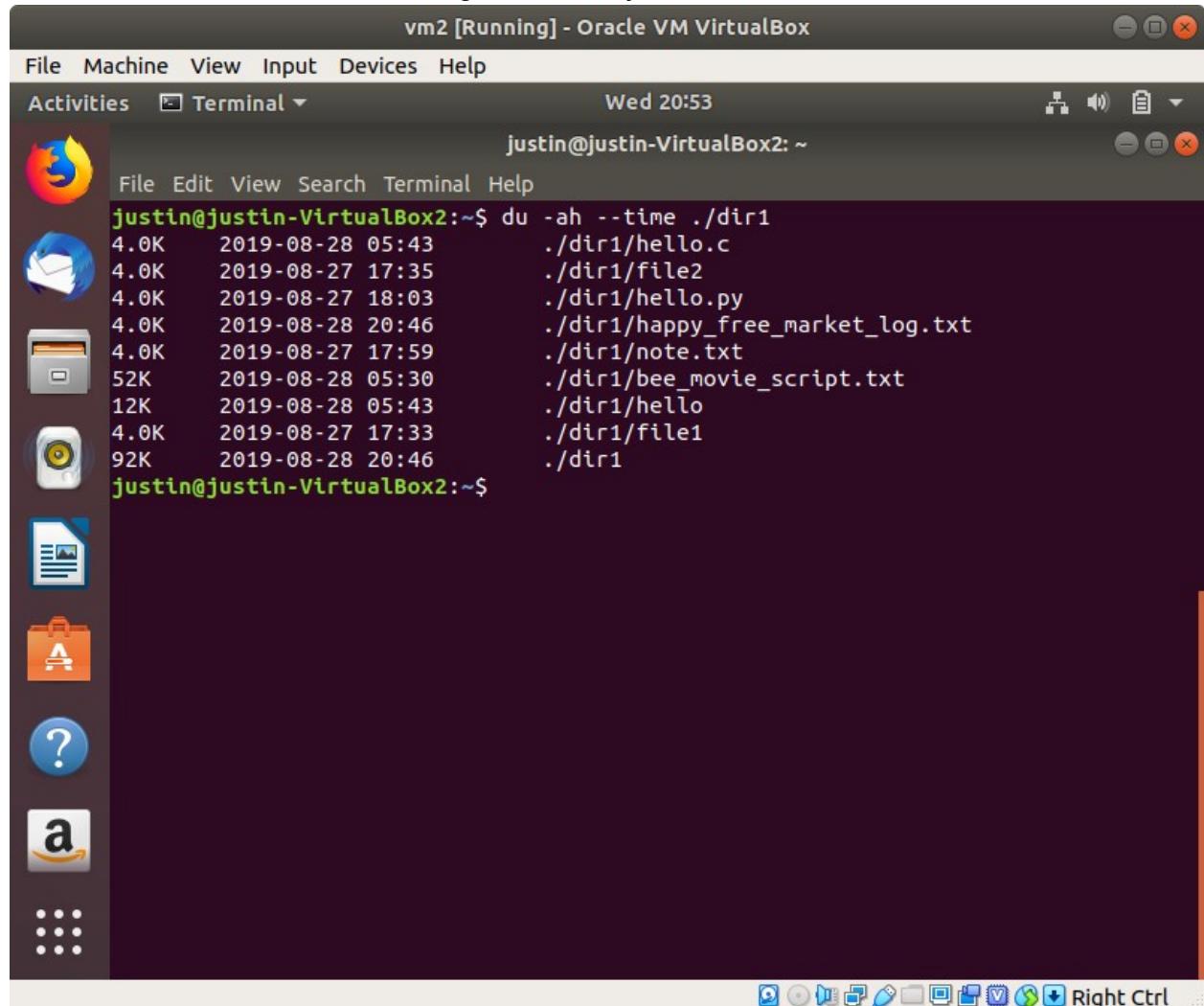
u. kill - terminate a running process



v. killall - terminate all processes with the provided program name



w. du - Estimate the file sizes in the given directory



The image shows a screenshot of an Ubuntu desktop environment running inside Oracle VM VirtualBox. The terminal window is titled "vm2 [Running] - Oracle VM VirtualBox". The terminal session shows the command "du -ah --time ./dir1" being run, listing file sizes and modification times for files in the directory "dir1". The desktop interface includes a dock with icons for various applications like Firefox, Mail, and Files.

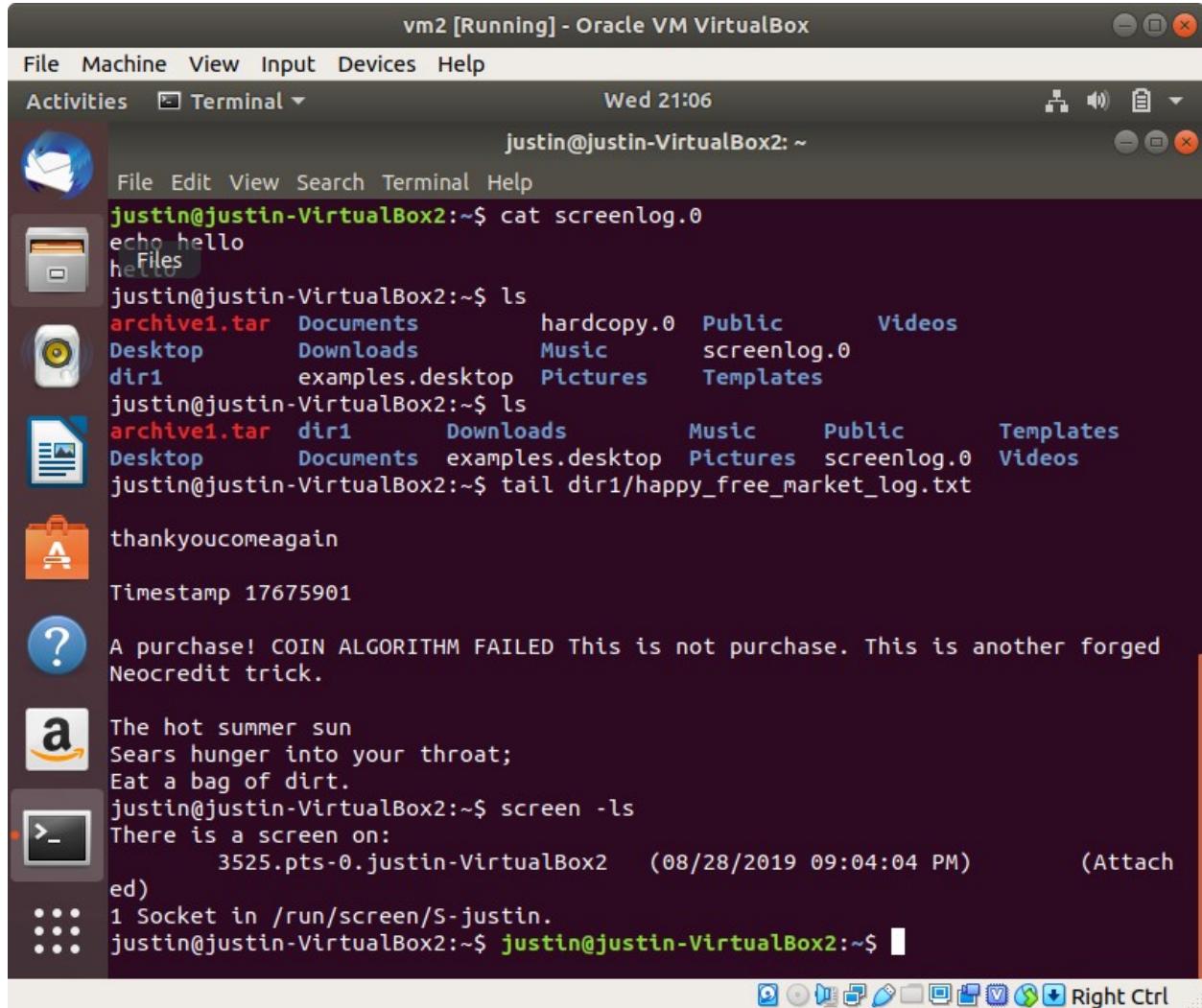
```
justin@justin-VirtualBox2:~$ du -ah --time ./dir1
4.0K    2019-08-28 05:43      ./dir1/hello.c
4.0K    2019-08-27 17:35      ./dir1/file2
4.0K    2019-08-27 18:03      ./dir1/hello.py
4.0K    2019-08-28 20:46      ./dir1/happy_free_market_log.txt
4.0K    2019-08-27 17:59      ./dir1/note.txt
52K    2019-08-28 05:30      ./dir1/bee_movie_script.txt
12K    2019-08-28 05:43      ./dir1/hello
4.0K    2019-08-27 17:33      ./dir1/file1
92K    2019-08-28 20:46      ./dir1
justin@justin-VirtualBox2:~$
```

x. df - Display the filesystem usage and disk availability

The screenshot shows a Linux desktop environment with a terminal window open. The terminal window title is "vm2 [Running] - Oracle VM VirtualBox". The terminal content displays the output of the "df -h" command, showing disk usage statistics. The desktop background is dark, and there are various icons in the dock at the bottom.

```
justin@justin-VirtualBox2:~$ df -h
Filesystem      Size  Used Avail Use% Mounted on
udev            1.9G   0    1.9G  0% /dev
tmpfs           395M  1.3M  394M  1% /run
/dev/sda1        25G   6.3G  18G  27% /
tmpfs           2.0G   0    2.0G  0% /dev/shm
tmpfs           5.0M  4.0K  5.0M  1% /run/lock
tmpfs           2.0G   0    2.0G  0% /sys/fs/cgroup
/dev/loop0       21M   21M   0 100% /snap/gnome-logs/25
/dev/loop5       13M   13M   0 100% /snap/gnome-characters/69
/dev/loop2       141M  141M   0 100% /snap/gnome-3-26-1604/59
/dev/loop1       3.4M  3.4M   0 100% /snap/gnome-system-monitor/36
/dev/loop3       1.7M  1.7M   0 100% /snap/gnome-calculator/154
/dev/loop4       89M   89M   0 100% /snap/core/7396
/dev/loop6       141M  141M   0 100% /snap/gnome-3-26-1604/90
/dev/loop7       87M   87M   0 100% /snap/core/4486
tmpfs           395M  28K  395M  1% /run/user/1000
/dev/loop8       55M   55M   0 100% /snap/core18/1074
/dev/loop9       1.0M  1.0M   0 100% /snap/gnome-logs/61
/dev/loop10      3.8M  3.8M   0 100% /snap/gnome-system-monitor/100
/dev/loop11      4.2M  4.2M   0 100% /snap/gnome-calculator/406
/dev/loop12      15M   15M   0 100% /snap/gnome-characters/296
/dev/loop13      150M  150M   0 100% /snap/gnome-3-28-1804/71
/dev/loop14      43M   43M   0 100% /snap/gtk-common-themes/1313
justin@justin-VirtualBox2:~$ df -h /
Filesystem      Size  Used Avail Use% Mounted on
/dev/sda1        25G   6.3G  18G  27% /
justin@justin-VirtualBox2:~$
```

y. screen - run processes in the background, with command logging functionalities



The screenshot shows a Linux desktop environment with a terminal window open in a window titled "vm2 [Running] - Oracle VM VirtualBox". The terminal window has a dark background and contains the following text:

```
justin@justin-VirtualBox2:~$ cat screenlog.0
echo hello
hello

justin@justin-VirtualBox2:~$ ls
archive1.tar  Documents      hardcopy.0  Public       Videos
Desktop       Downloads      Music        screenlog.0
dir1          examples.desktop Pictures    Templates
justin@justin-VirtualBox2:~$ ls
archive1.tar  dir1          Downloads     Music       Public      Templates
Desktop       Documents     examples.desktop Pictures  screenlog.0  Videos
justin@justin-VirtualBox2:~$ tail dir1/happy_free_market_log.txt

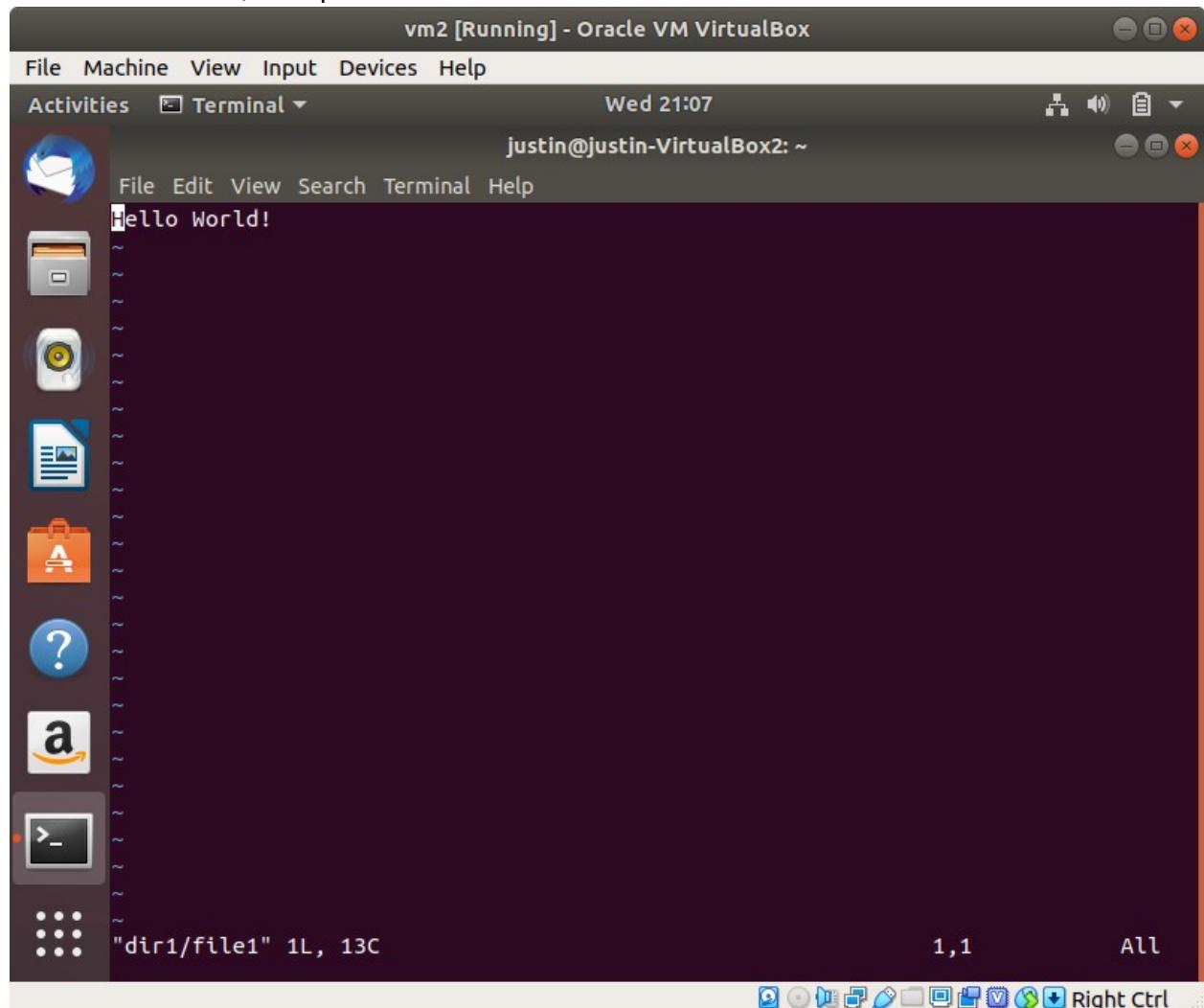
thankyoucomeagain
Timestamp 17675901

A purchase! COIN ALGORITHM FAILED This is not purchase. This is another forged Neocredit trick.

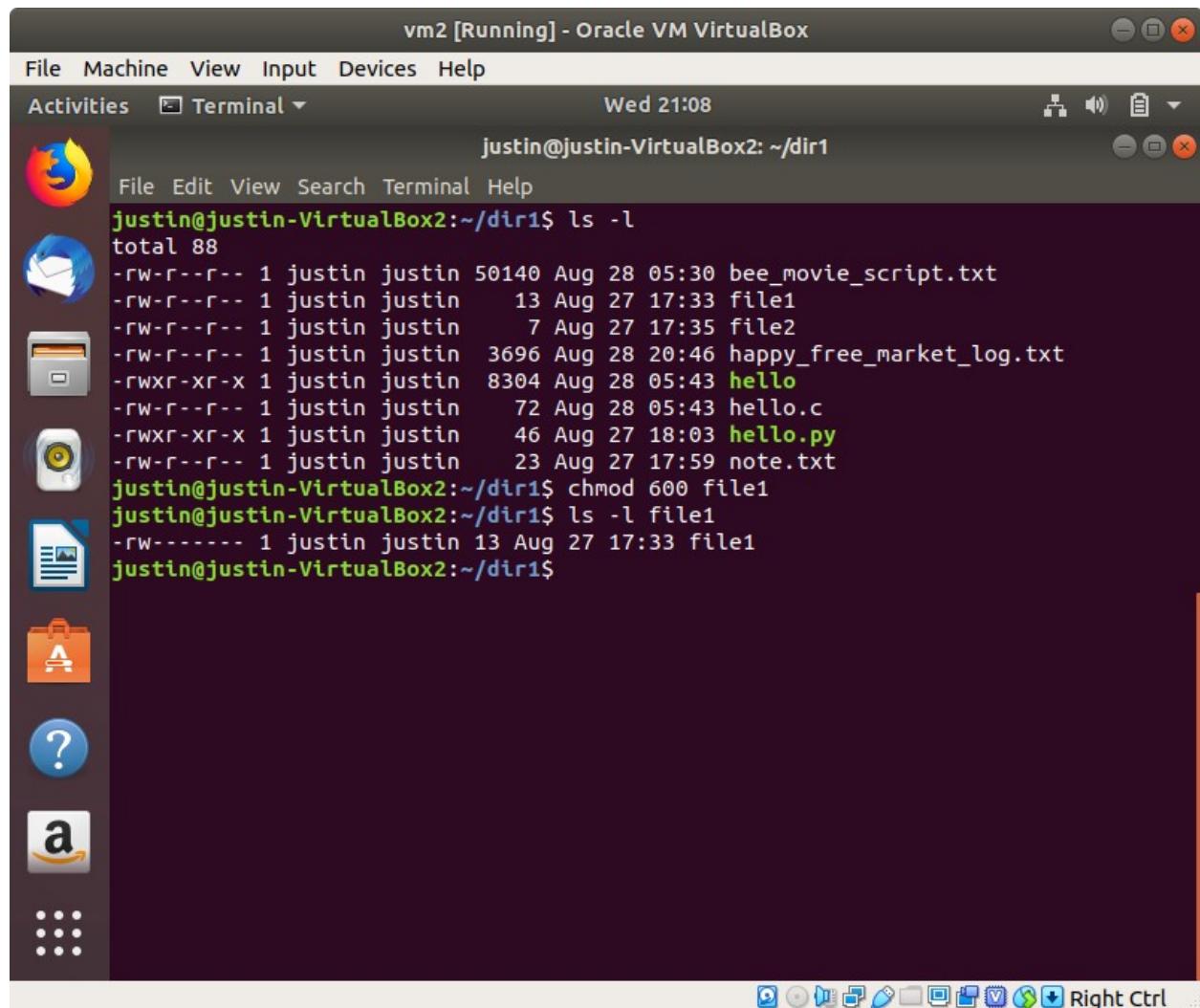
The hot summer sun
Sears hunger into your throat;
Eat a bag of dirt.
justin@justin-VirtualBox2:~$ screen -ls
There is a screen on:
      3525.pts-0.justin-VirtualBox2  (08/28/2019 09:04:04 PM)  (Attached)
      1 Socket in /run/screen/S-justin.
justin@justin-VirtualBox2:~$ justin@justin-VirtualBox2:~$
```

The terminal window includes a file manager sidebar on the left and a dock at the bottom with icons for various applications like a browser, file manager, and system tools.

z. vim - Text editor, VI iMproved



aa. chmod - change the permissions of a file



The image shows a screenshot of an Ubuntu desktop environment running inside Oracle VM VirtualBox. The desktop has a dark theme with a dock on the left containing icons for various applications like a browser, email, file manager, and system tools. A terminal window is open in the center, showing a Linux command-line session. The terminal window title is "vm2 [Running] - Oracle VM VirtualBox". The session starts with "justin@justin-VirtualBox2: ~/dir1", followed by an "ls -l" command showing a list of files. Then, a "chmod 600 file1" command is run, changing the permissions of "file1". Finally, another "ls -l file1" command is run to show the updated permissions.

```
justin@justin-VirtualBox2:~/dir1$ ls -l
total 88
-rw-r--r-- 1 justin justin 50140 Aug 28 05:30 bee_movie_script.txt
-rw-r--r-- 1 justin justin     13 Aug 27 17:33 file1
-rw-r--r-- 1 justin justin      7 Aug 27 17:35 file2
-rw-r--r-- 1 justin justin   3696 Aug 28 20:46 happy_free_market_log.txt
-rwxr-xr-x 1 justin justin  8304 Aug 28 05:43 hello
-rw-r--r-- 1 justin justin     72 Aug 28 05:43 hello.c
-rwxr-xr-x 1 justin justin     46 Aug 27 18:03 hello.py
-rw-r--r-- 1 justin justin    23 Aug 27 17:59 note.txt
justin@justin-VirtualBox2:~/dir1$ chmod 600 file1
justin@justin-VirtualBox2:~/dir1$ ls -l file1
-rw----- 1 justin justin 13 Aug 27 17:33 file1
justin@justin-VirtualBox2:~/dir1$
```

bb. chown - change the owner of a file

cc. useradd - add a user to the system

The screenshot shows a Linux desktop environment with a dark theme. At the top is a window titled "vm2 [Running] - Oracle VM VirtualBox". Below the title bar is a menu bar with "File", "Machine", "View", "Input", "Devices", and "Help". To the right of the menu bar is the date and time "Wed 21:14". A docked application, "LibreOffice Writer", is visible on the left side of the screen. The main workspace contains a terminal window with the following command history:

```
justin@justin-VirtualBox2:~/dir1$ ls -l file1
-rw----- 1 justin justin 13 Aug 27 17:33 file1
justin@justin-VirtualBox2:~/dir1$ sudo useradd guest
justin@justin-VirtualBox2:~/dir1$ sudo chown guest file1
justin@justin-VirtualBox2:~/dir1$ ls -l file1
-rw----- 1 guest justin 13 Aug 27 17:33 file1
justin@justin-VirtualBox2:~/dir1$
```

The terminal window has a dark background and light-colored text. The docked LibreOffice Writer icon is highlighted with a blue border.

dd. man - show the manual of a command

vm2 [Running] - Oracle VM VirtualBox

File Machine View Input Devices Help

Activities Terminal justin@justin-VirtualBox2: ~

Firefox Web Browser File Edit View Search Terminal Help

MAN(1) Manual pager utils MAN(1)

NAME
man - an interface to the on-line reference manuals

SYNOPSIS

```
man [-C file] [-d] [-D] [--warnings[=warnings]] [-R encoding] [-L locale] [-m system[,...]] [-M path] [-S list] [-e extension] [-i|-I] [--regex|--wildcard] [--names-only] [-a] [-u] [--no-subpages] [-P pager] [-r prompt] [-7] [-E encoding] [--no-hyphenation] [--no-justification] [-p string] [-t] [-T[device]] [-H[browser]] [-X[dpi]] [-Z] [[section] page[.section] ...] ...
man -k [apropos options] regexp ...
man -K [-w|-W] [-S list] [-i|-I] [--regex] [section] term ...
man -f [whatis options] page ...
man -l [-C file] [-d] [-D] [--warnings[=warnings]] [-R encoding] [-L locale] [-P pager] [-r prompt] [-7] [-E encoding] [-p string] [-t] [-T[device]] [-H[browser]] [-X[dpi]] [-Z] file ...
man -w|-W [-C file] [-d] [-D] page ...
man -c [-C file] [-d] [-D] page ...
man [-?V]
```

DESCRIPTION

man is the system's manual pager. Each page argument given to **man** is normally the name of a program, utility or function. The manual page associated with each of these arguments is then found and displayed. A section, if provided, will direct **man** to look only in that section

Manual page man(1) line 1 (press h for help or q to quit)

Right Ctrl

ee. locate - find a file by name, in the given directory

The screenshot shows a Linux desktop environment with a dark theme. A terminal window titled "vm2 [Running] - Oracle VM VirtualBox" is open, displaying a command-line session. The session starts with "File Edit View Search Terminal Help", followed by "justin@justin-VirtualBox2: ~". The user runs "ls dir1" which lists files: bee_movie_script.txt, file2, file1, happy_free_market_log.txt, hello, hello.c, and note.txt. Then, "locate note.txt" is run, showing the result "/home/justin/dir1/note.txt". The terminal ends with "justin@justin-VirtualBox2: ~\$". On the left, there is a vertical dock with icons for various applications: Firefox, Evolution, Nautilus, Eye of GNOME, Photos, Files, Activities, Applications, Help, and a terminal icon.

ff. find - find a file with the given filename, display all matches.

The screenshot shows a Linux desktop environment with a dark theme. A terminal window titled "vm2 [Running] - Oracle VM VirtualBox" is open, showing the command-line interface. The terminal window has a dark background with light-colored text. The window title bar includes the window name, application name ("Terminal"), and system status ("Wed 21:24"). The terminal window contains the following text:

```
File Edit View Search Terminal Help  
justin@justin-VirtualBox2:~$ find . -name happy*  
. ./dir1/happy_free_market_log.txt  
justin@justin-VirtualBox2:~$
```

To the left of the terminal window is a vertical dock containing icons for various applications: Firefox, Nautilus (file manager), System Settings, Dash (application menu), Help, Amazon, and a terminal icon. The dock has a dark background with light-colored icons. At the bottom of the screen is a horizontal dock with various icons for system functions like network, volume, and brightness control, along with a "Right Ctrl" key indicator.

gg. sed - Match and replace text from a provided text stream

The screenshot shows a Linux desktop environment with a terminal window open in a virtual machine named "vm2 [Running]". The terminal window title is "vm2 [Running] - Oracle VM VirtualBox". The terminal window contains the following text:

```
File Edit View Search Terminal Help
justin@justin-VirtualBox2:~/dir1$ cat happy.txt
thankyoucomeagain
thankyoucomeagain
thankyoucomeagain
thankyoucomEagain
thaNkucomEaGaiN
thankucumegin
thanksucuumagain
thankyoucomeagain
thankyoucomeagain
justin@justin-VirtualBox2:~/dir1$ sed 's/thank/Thank/g' happy.txt
Thankyoucomeagain
ThankyoucomEagain
thaNkucomEaGaiN
thankucumegin
Thanksucuumagain
Thankyoucomeagain
Thankyoucomeagain
justin@justin-VirtualBox2:~/dir1$
```

The desktop interface includes a dock with various icons for applications like Firefox, LibreOffice Writer, and Amazon. The system tray at the bottom shows icons for network, battery, and system status.

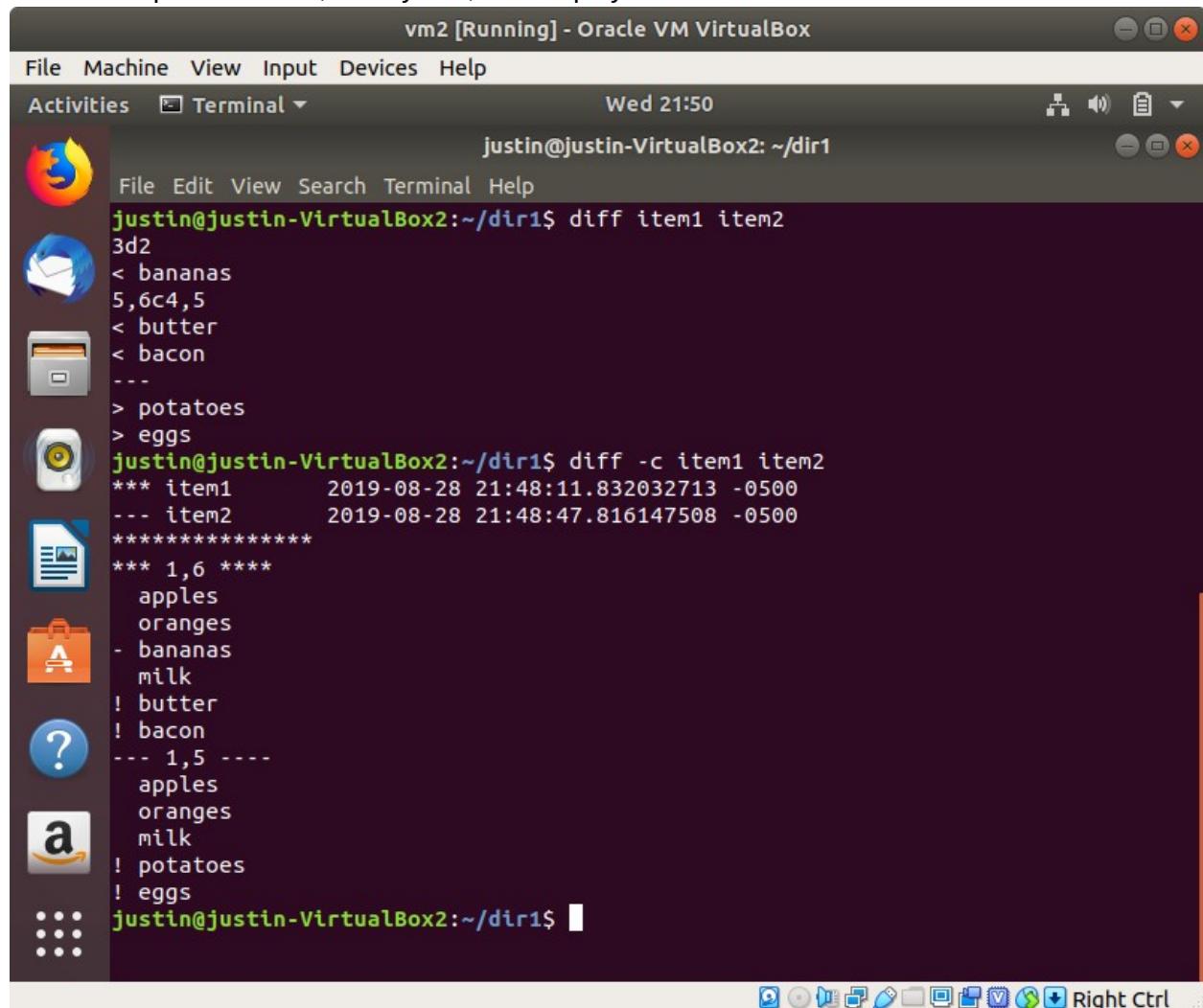
hh. awk - an interpreted programming language for text processing (matching, formatting, etc)

The screenshot shows a Linux desktop environment with a dark theme. A terminal window titled "vm2 [Running] - Oracle VM VirtualBox" is open, displaying the command "awk '/thank/ {print NR,\$0}' happy_free_market_log.txt". The output of the command is shown in green text:

```
justin@justin-VirtualBox2:~/dir1$ awk '/thank/ {print NR,$0}' happy_free_market_log.txt
13 thankyoucomeagain
27 thankyoucomeagain
33 thankyoucomeagain
43 thankyoucomEagain
55 thankucumegin
61 thanksucuumagain
71 thankyoucomeagain
89 thankyoucomeagain
justin@justin-VirtualBox2:~/dir1$
```

The desktop interface includes a dock at the bottom with various icons, a vertical application menu on the left, and a system tray at the bottom right.

ii. diff - compare two files, line by line, and display the differences



The screenshot shows a Linux desktop environment with a terminal window open. The terminal window is titled "vm2 [Running] - Oracle VM VirtualBox". The window title bar also displays "File Machine View Input Devices Help" and "Activities Terminal". The status bar at the top right shows "Wed 21:50" and the user "justin@justin-VirtualBox2: ~/dir1". The terminal window contains the following output from the "diff" command:

```
justin@justin-VirtualBox2:~/dir1$ diff item1 item2
3d2
< bananas
5,6c4,5
< butter
< bacon
---
> potatoes
> eggs
justin@justin-VirtualBox2:~/dir1$ diff -c item1 item2
*** item1      2019-08-28 21:48:11.832032713 -0500
--- item2      2019-08-28 21:48:47.816147508 -0500
*****
*** 1,6 ****
    apples
    oranges
- bananas
    milk
! butter
! bacon
--- 1,5 ----
    apples
    oranges
    milk
! potatoes
! eggs
justin@justin-VirtualBox2:~/dir1$
```

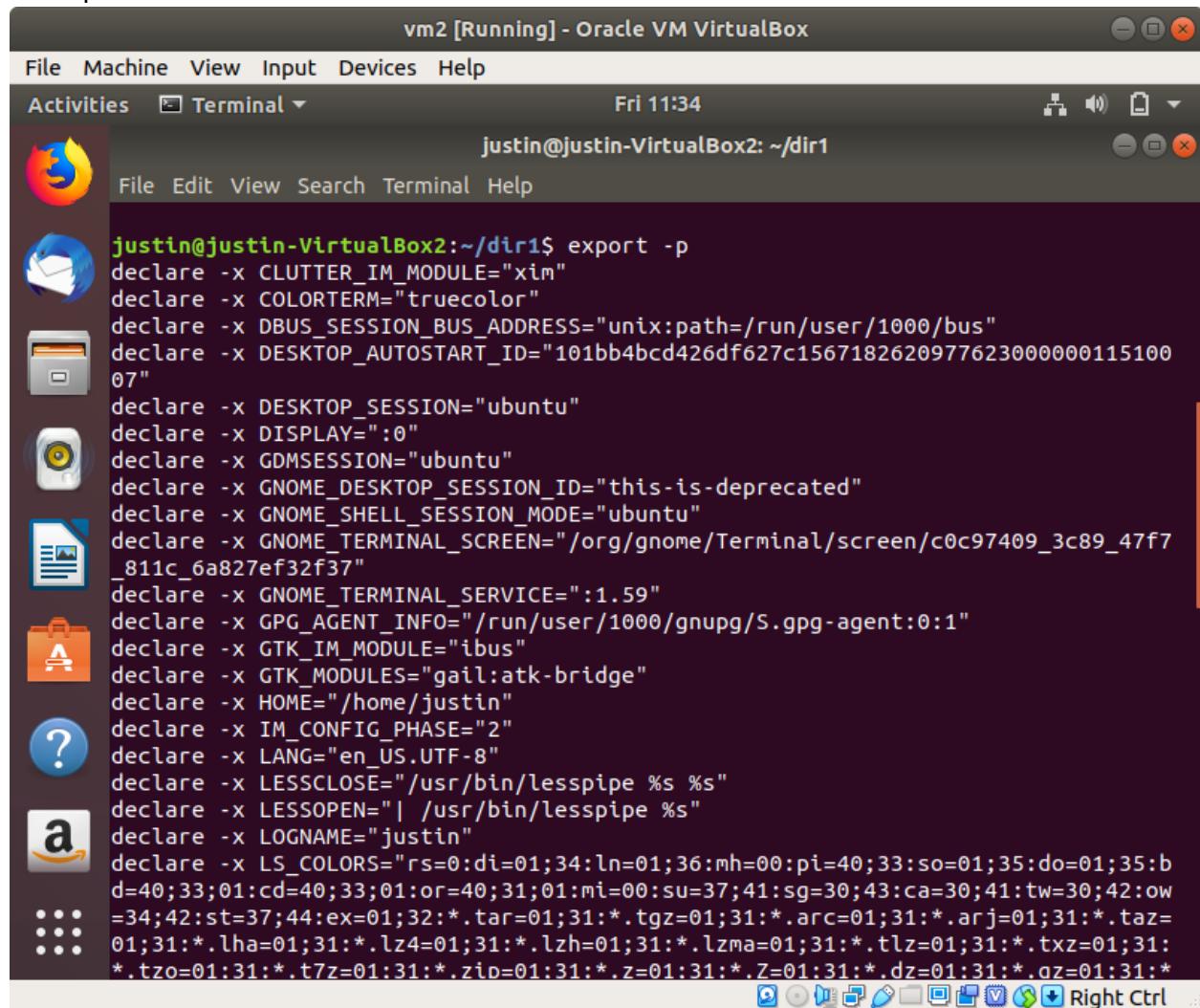
The terminal window has a dark background and light-colored text. The desktop interface includes a dock with various icons for applications like a web browser, email, file manager, and system tools.

jj. sort - sort the file by line (alphabetically/numerically)

The screenshot shows a Linux desktop environment with a dark theme. A terminal window titled "vm2 [Running] - Oracle VM VirtualBox" is open, displaying the output of a "sort" command. The terminal window includes a menu bar with File, Machine, View, Input, Devices, Help, and Activities. The Activities menu is currently active. The desktop background features a vertical dock on the left side with icons for various applications: Firefox, Evolution, Files, Dash, Help, Amazon, and a terminal icon. The system tray at the bottom shows several icons, including a network connection, battery status, and system notifications. The terminal window shows the command "sort -k1 -r happy_1.txt" being run, and its output, which consists of several lines of text starting with numbers 89, 71, 61, 55, 43, 33, 27, and 13, all followed by the string "thankyoucomeagain".

```
justin@justin-VirtualBox2:~/dir1$ sort -k1 -r happy_1.txt
89 thankyoucomeagain
71 thankyoucomeagain
61 thankscuoomagain
55 thankucumegin
43 thankyoucomEagain
33 thankyoucomeagain
27 thankyoucomeagain
13 thankyoucomeagain
justin@justin-VirtualBox2:~/dir1$
```

kk. export - Show all bash environment variables



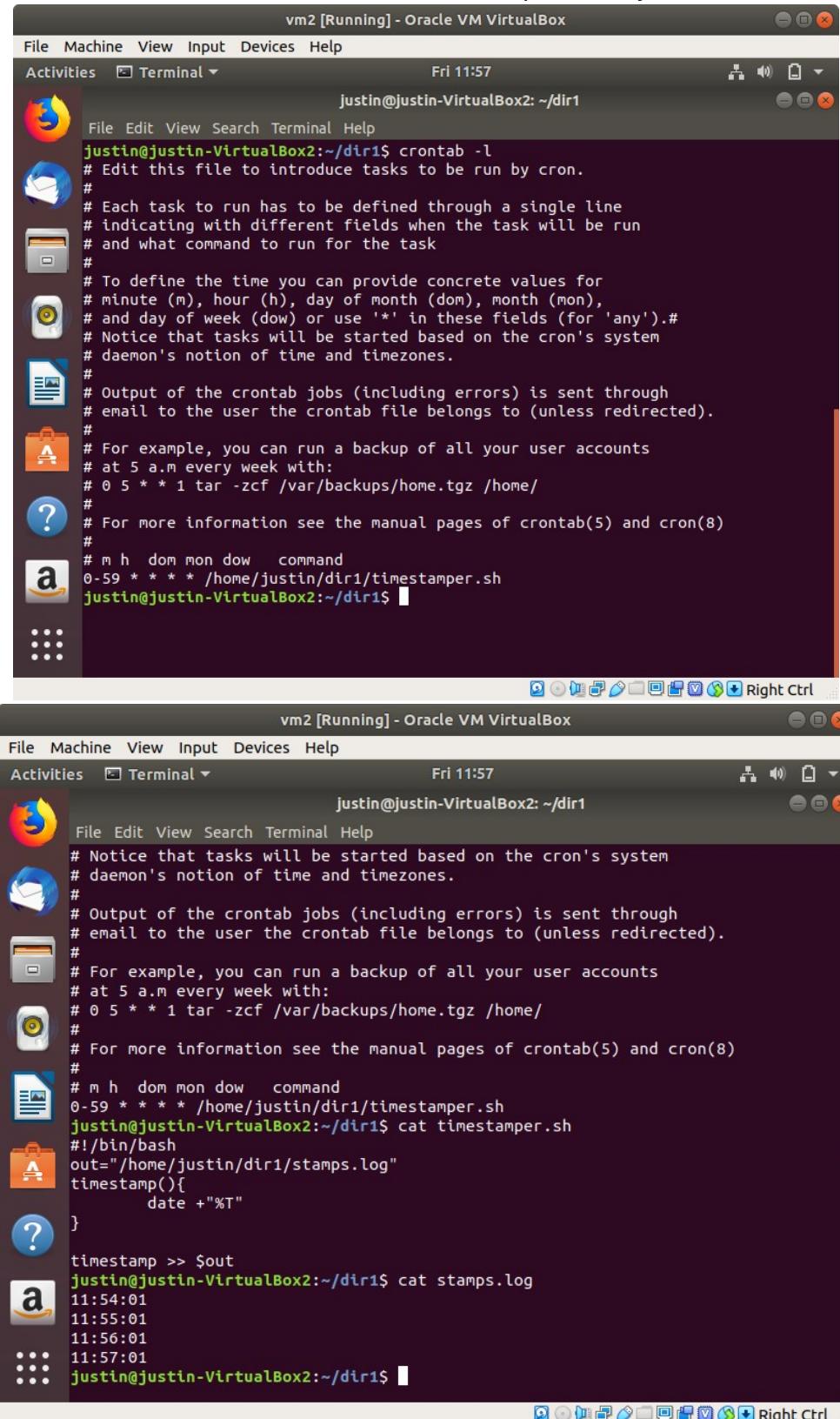
The screenshot shows a Linux desktop environment within a VirtualBox window titled "vm2 [Running] - Oracle VM VirtualBox". The desktop has a dark theme with icons for various applications like Firefox, Evolution, Nautilus, GDM, and others. A terminal window is open, showing the command "justin@justin-VirtualBox2:~/dir1\$ export -p" followed by a long list of environment variable declarations. The terminal window has a dark background and light-colored text.

```
justin@justin-VirtualBox2:~/dir1$ export -p
declare -x CLUTTER_IM_MODULE="xim"
declare -x COLORTERM="truecolor"
declare -x DBUS_SESSION_BUS_ADDRESS="unix:path=/run/user/1000/bus"
declare -x DESKTOP_AUTOSTART_ID="101bb4bcd426df627c1567182620977623000000115100
07"
declare -x DESKTOP_SESSION="ubuntu"
declare -x DISPLAY=":0"
declare -x GDMSESSION="ubuntu"
declare -x GNOME_DESKTOP_SESSION_ID="this-is-deprecated"
declare -x GNOME_SHELL_SESSION_MODE="ubuntu"
declare -x GNOME_TERMINAL_SCREEN="/org/gnome/Terminal/screen/c0c97409_3c89_47f7
_811c_6a827ef32f37"
declare -x GNOME_TERMINAL_SERVICE=:1.59"
declare -x GPG_AGENT_INFO="/run/user/1000/gnupg/S.gpg-agent:0:1"
declare -x GTK_IM_MODULE="ibus"
declare -x GTK_MODULES="gail:atk-bridge"
declare -x HOME="/home/justin"
declare -x IM_CONFIG_PHASE="2"
declare -x LANG="en_US.UTF-8"
declare -x LESSCLOSE="/usr/bin/lesspipe %s %s"
declare -x LESSOPEN="| /usr/bin/lesspipe %s"
declare -x LOGNAME="justin"
declare -x LS_COLORS="rs=0:di=01;34:ln=01;36:mh=00:pi=40;33:so=01;35:do=01;35:b
d=40;33;01:cd=40;33;01:or=40;31;01:mi=00:su=37;41:sg=30;43:ca=30;41:tw=30;42:ow
=34;42:st=37;44:ex=01;32:*.tar=01;31:*.tgz=01;31:*.arc=01;31:*.arj=01;31:*.taz=
01;31:*.lha=01;31:*.lz4=01;31:*.lzh=01;31:*.lzma=01;31:*.tlz=01;31:*.txz=01;31:
*.tzo=01:31:*.t7z=01:31:*.zip=01:31:*.z=01:31:*.Z=01:31:*.dz=01:31:*.qz=01:31:*
```

II. `pwd` - print current working directory path

The screenshot shows a Linux desktop environment with a dark theme. At the top, the window title is "vm2 [Running] - Oracle VM VirtualBox". The menu bar includes "File", "Machine", "View", "Input", "Devices", and "Help". Below the menu is a toolbar with "Activities" and "Terminal" buttons. The date and time "Thu 17:31" are displayed. On the left is a vertical dock containing icons for various applications: Firefox, Evolution, Nautilus, GIMP, LibreOffice Writer, LibreOffice Calc, a folder with an 'A' icon, a question mark icon, and an Amazon logo. The main workspace contains a terminal window titled "justin@justin-VirtualBox2: ~/dir1". The terminal displays the command "justin@justin-VirtualBox2:~/dir1\$ pwd" followed by the output "/home/justin/dir1". The bottom of the screen features a dock with icons for various system functions like volume control, brightness, and network.

mm. crontab - schedule tasks to the cron daemon to run periodically.



vm2 [Running] - Oracle VM VirtualBox

File Machine View Input Devices Help

Activities Terminal Fri 11:57

justin@justin-VirtualBox2: ~/dir1\$ crontab -l

```
# 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  
0-59 * * * * /home/justin/dir1/timestamper.sh
```

justin@justin-VirtualBox2:~/dir1\$

vm2 [Running] - Oracle VM VirtualBox

File Machine View Input Devices Help

Activities Terminal Fri 11:57

justin@justin-VirtualBox2: ~/dir1\$

```
File Edit View Search Terminal Help  
# 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  
0-59 * * * * /home/justin/dir1/timestamper.sh
```

justin@justin-VirtualBox2:~/dir1\$ cat timestamper.sh

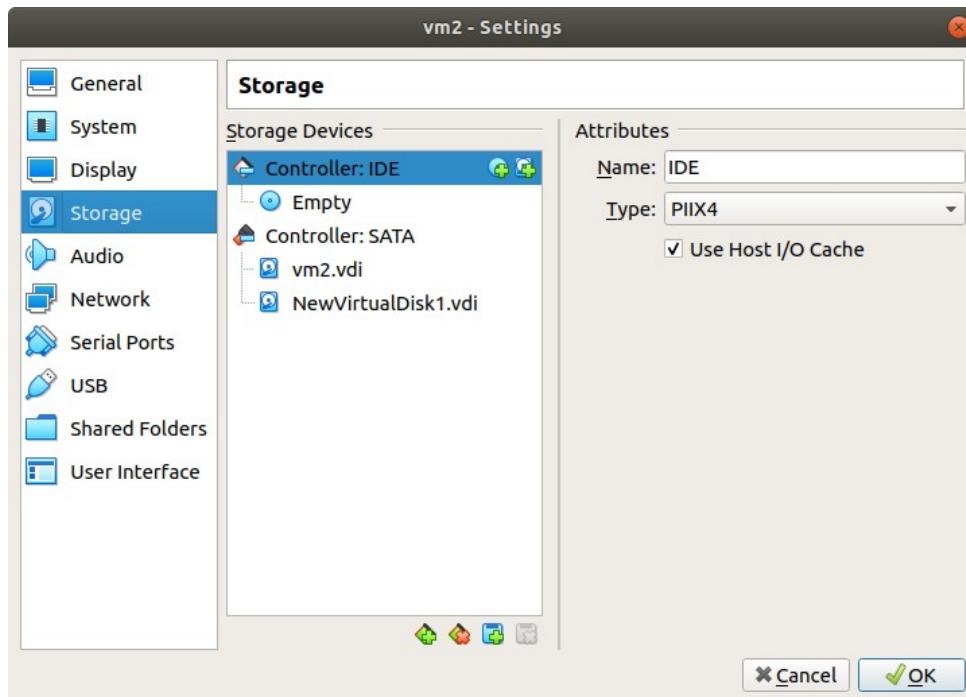
```
#!/bin/bash  
out="/home/justin/dir1/stamps.log"  
timestamp(){  
    date +"%T"  
}  
  
timestamp >> $out
```

justin@justin-VirtualBox2:~/dir1\$ cat stamps.log

```
11:54:01  
11:55:01  
11:56:01  
11:57:01
```

justin@justin-VirtualBox2:~/dir1\$

nn1. Create a disk in VirtualBox



nn2. List the available devices with lsblk

```
justin@justin-VirtualBox2:~$ sudo lsblk -o NAME,FSTYPE,SIZE,MOUNTPOINT,LABEL
NAME   FSTYPE      SIZE MOUNTPOINT          LABEL
loop0   squashfs    1.6M /snap/gnome-calculator/154
loop1   squashfs    54.4M /snap/core18/1074
loop2   squashfs    21M  /snap/gnome-logs/25
loop3   squashfs    86.6M /snap/core/4486
loop4   squashfs    140.7M /snap/gnome-3-26-1604/90
loop5   squashfs    88.7M /snap/core/7396
loop6   squashfs    3.3M  /snap/gnome-system-monitor/36
loop7   squashfs    81.7M /snap/emacs/67
loop8   squashfs    140M  /snap/gnome-3-26-1604/59
loop9   squashfs    14.8M /snap/gnome-characters/296
loop10  squashfs    149.9M /snap/gnome-3-28-1804/71
loop11  squashfs    3.7M  /snap/gnome-system-monitor/100
loop12  squashfs    42.8M /snap/gtk-common-themes/1313
loop13  squashfs    1008K /snap/gnome-logs/61
loop14  squashfs    14.8M /snap/gnome-characters/317
loop15  squashfs    4M    /snap/gnome-calculator/406
sda
└─sda1 ext4       25G /
sdb
sr0           1024M
```

nn3. Create a new partition with fdisk

```
File Machine View Input Devices Help
Activities Terminal Fri 12:27
justin@justin-VirtualBox2: ~
File Edit View Search Terminal Help
sdb      512M
sr0     1024M
justin@justin-VirtualBox2:~$ sudo fdisk /dev/sdb

Welcome to fdisk (util-linux 2.31.1).
Changes will remain in memory only, until you decide to write them.
Be careful before using the write command.

Device does not contain a recognized partition table.
Created a new DOS disklabel with disk identifier 0x894a02d2.

Command (m for help): n
Partition type
  p  primary (0 primary, 0 extended, 4 free)
  e  extended (container for logical partitions)
Select (default p): p
Partition number (1-4, default 1): 1
First sector (2048-1048575, default 2048):
Last sector, +sectors or +size{K,M,G,T,P} (2048-1048575, default 1048575):

Created a new partition 1 of type 'Linux' and of size 511 MiB.

Command (m for help): w
The partition table has been altered.
Calling ioctl() to re-read partition table.
Syncing disks.

justin@justin-VirtualBox2:~$
```

nn4. Mount the partition to the filesystem

```
File Machine View Input Devices Help
Activities Terminal Fri 12:39
justin@justin-VirtualBox2: ~
File Edit View Search Terminal Help
sdb      512M
└─sdb1 ext2      511M
sr0     1024M
justin@justin-VirtualBox2:~$ sudo mount /dev/sdb1 /media/newdisk1
justin@justin-VirtualBox2:~$ sudo lsblk -o NAME,FSTYPE,SIZE,MOUNTPOINT,LABEL
NAME   FSTYPE   SIZE MOUNTPOINT           LABEL
loop0  squashfs  1.6M /snap/gnome-calculator/154
loop1  squashfs  54.4M /snap/core18/1074
loop2  squashfs  21M  /snap/gnome-logs/25
loop3  squashfs  86.6M /snap/core/4486
loop4  squashfs  140.7M /snap/gnome-3-26-1604/90
loop5  squashfs  88.7M /snap/core/7396
loop6  squashfs  3.3M /snap/gnome-system-monitor/36
loop7  squashfs  81.7M /snap/emacs/67
loop8  squashfs  140M /snap/gnome-3-26-1604/59
loop9  squashfs  14.8M /snap/gnome-characters/296
loop10 squashfs  149.9M /snap/gnome-3-28-1804/71
loop11 squashfs  3.7M /snap/gnome-system-monitor/100
loop12 squashfs  42.8M /snap/gtk-common-themes/1313
loop13 squashfs  1008K /snap/gnome-logs/61
loop14 squashfs  14.8M /snap/gnome-characters/317
loop15 squashfs  4M   /snap/gnome-calculator/406
sda      25G
└─sda1 ext4      25G /
sdb      512M
└─sdb1 ext2      511M /media/newdisk1
sr0     1024M
justin@justin-VirtualBox2:~$
```

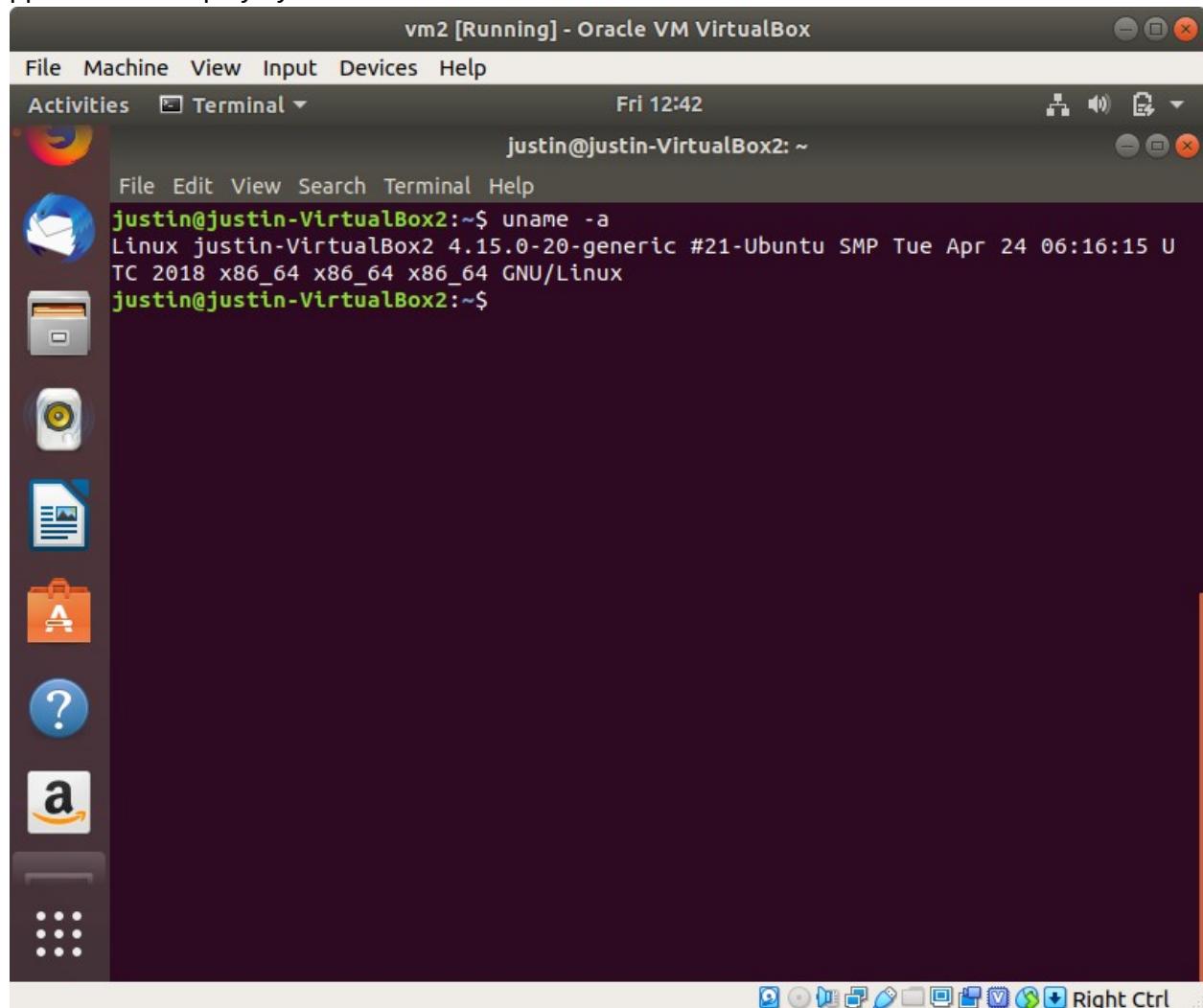
oo. passwd - change the password for a user

The screenshot shows a Linux desktop environment with a dark theme. At the top, the window title is "vm2 [Running] - Oracle VM VirtualBox". The menu bar includes "File", "Machine", "View", "Input", "Devices", and "Help". Below the menu is a docked panel titled "Activities" with a "Terminal" icon. The main workspace shows a terminal window with the following content:

```
File Edit View Search Terminal Help
justin@justin-VirtualBox2:~$ sudo passwd guest
Enter new UNIX password:
Retype new UNIX password:
passwd: password updated successfully
justin@justin-VirtualBox2:~$
```

The desktop background is a solid dark color. A vertical dock on the left contains icons for various applications: a browser, email, file manager, system settings, a camera, a document, a briefcase, help, and Amazon. The bottom of the screen features a dock with icons for a camera, file manager, terminal, and other system tools.

pp. uname - display system information of the current machine



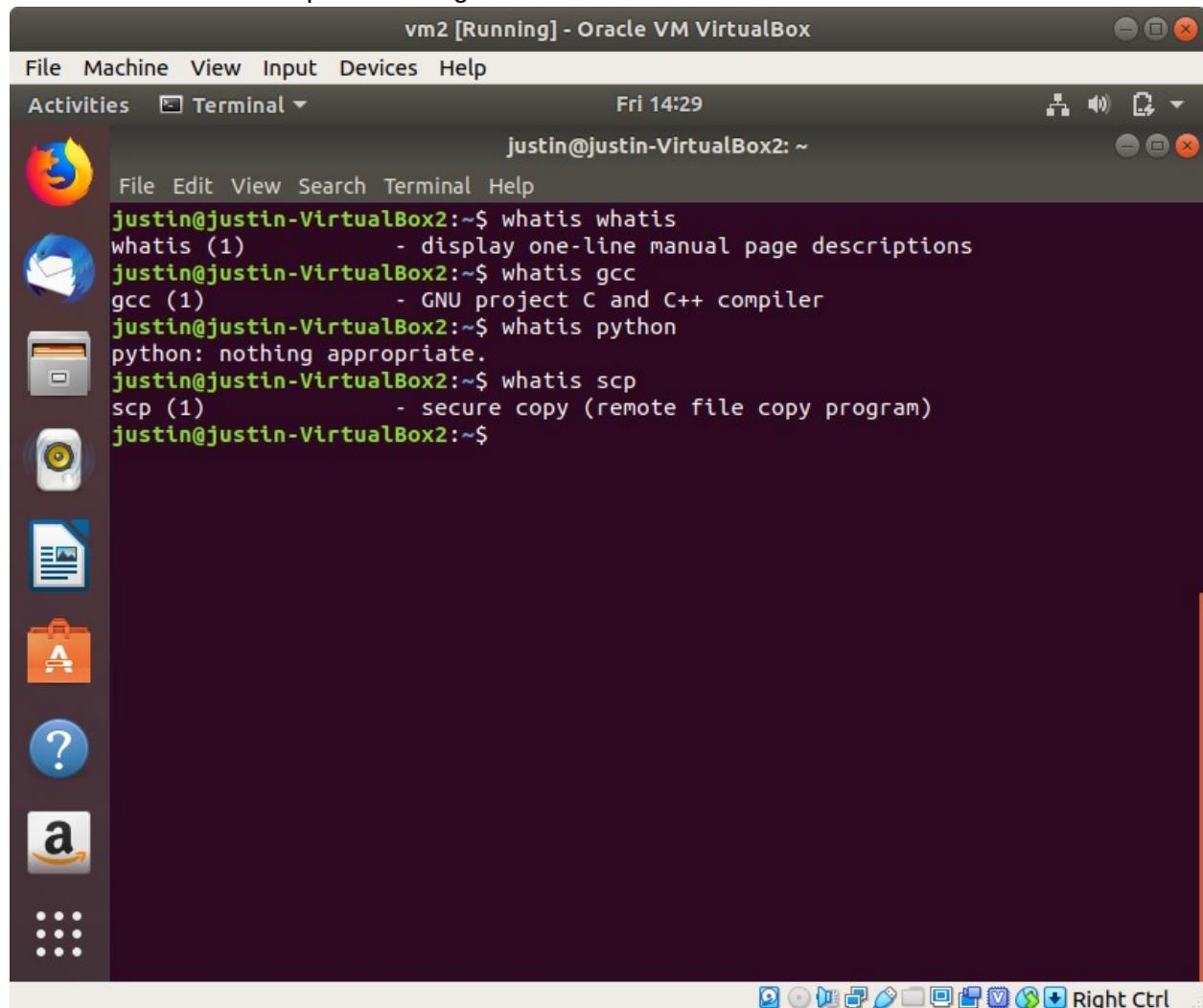
qq. whereis - Show the path of the executable of the given command

The screenshot shows a Linux desktop environment with a dark theme. A terminal window titled "vm2 [Running] - Oracle VM VirtualBox" is open, displaying the output of the "whereis" command. The terminal window includes a menu bar with File, Machine, View, Input, Devices, Help, and Activities. The Activities menu is currently selected. The terminal itself has a title bar showing "justin@justin-VirtualBox2: ~" and a status bar indicating the date and time as "Fri 14:29". The terminal content shows the following command-line session:

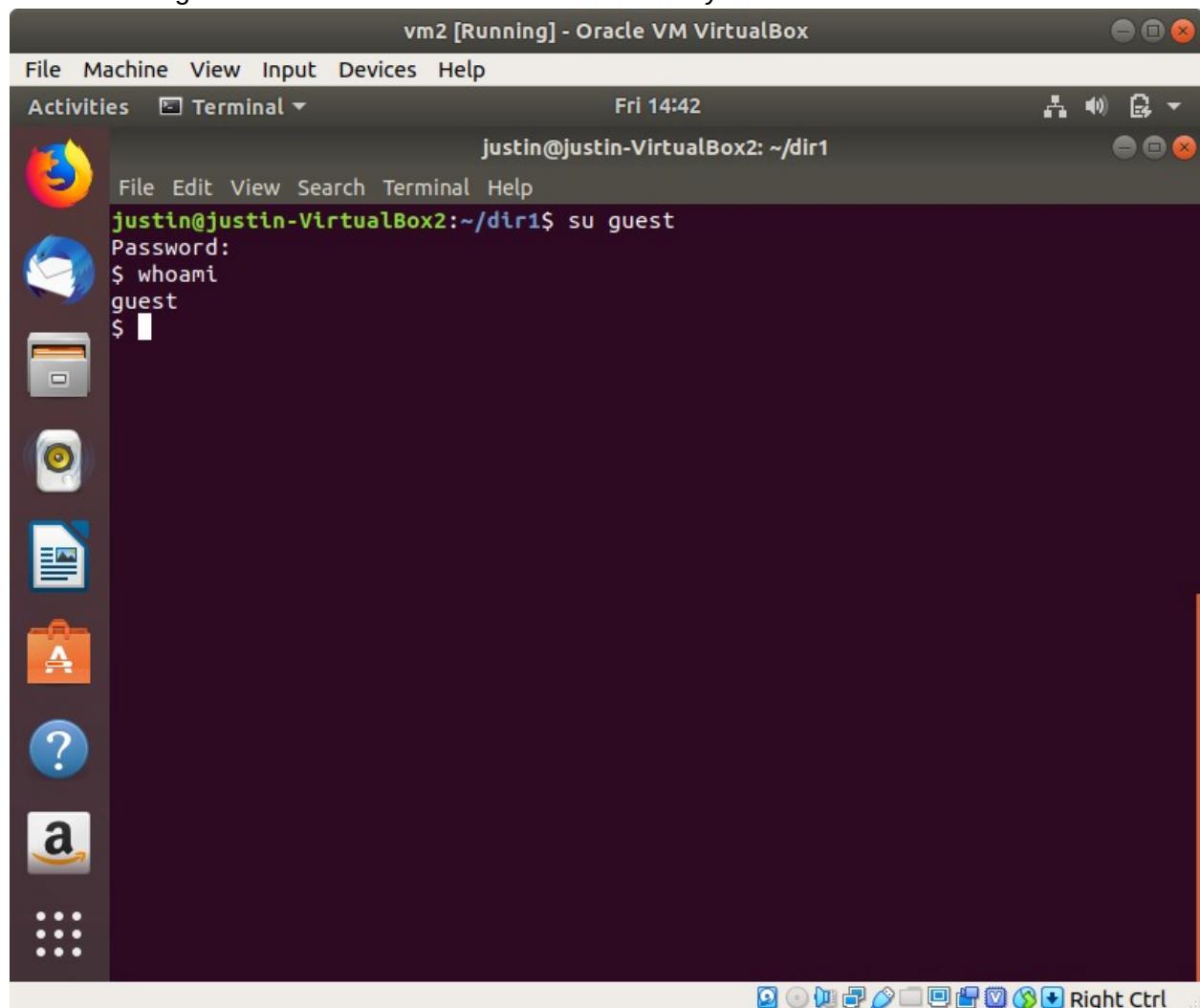
```
justin@justin-VirtualBox2:~$ whereis gcc
gcc: /usr/bin/gcc /usr/lib/gcc /usr/share/man/man1/gcc.1.gz
justin@justin-VirtualBox2:~$ whereis ip
ip: /bin/ip /sbin/ip /usr/share/man/man8/ip.8.gz /usr/share/man/man7/ip.7.gz
justin@justin-VirtualBox2:~$ whereis ssh
ssh: /usr/bin/ssh /etc/ssh /usr/share/man/man1/ssh.1.gz
justin@justin-VirtualBox2:~$
```

To the left of the terminal window is a vertical dock containing icons for various applications: Firefox, Evolution, Nautilus, GIMP, LibreOffice, Help, Amazon, and a terminal icon. At the bottom of the screen is a dock bar with several icons, including a clock, a file manager, a terminal, a browser, and other system utilities. The desktop background is a solid dark color.

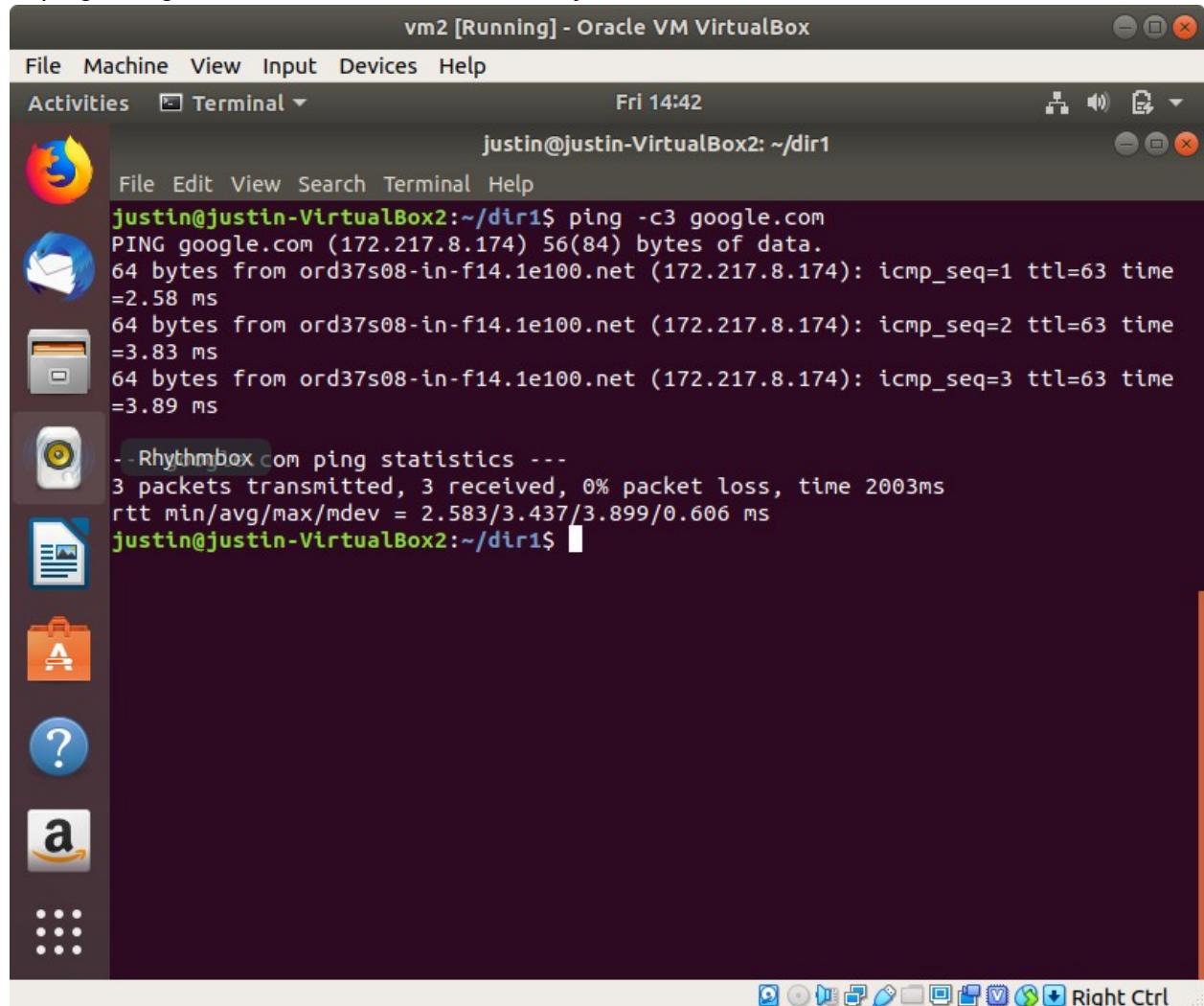
rr. whatis - Short description of the given command



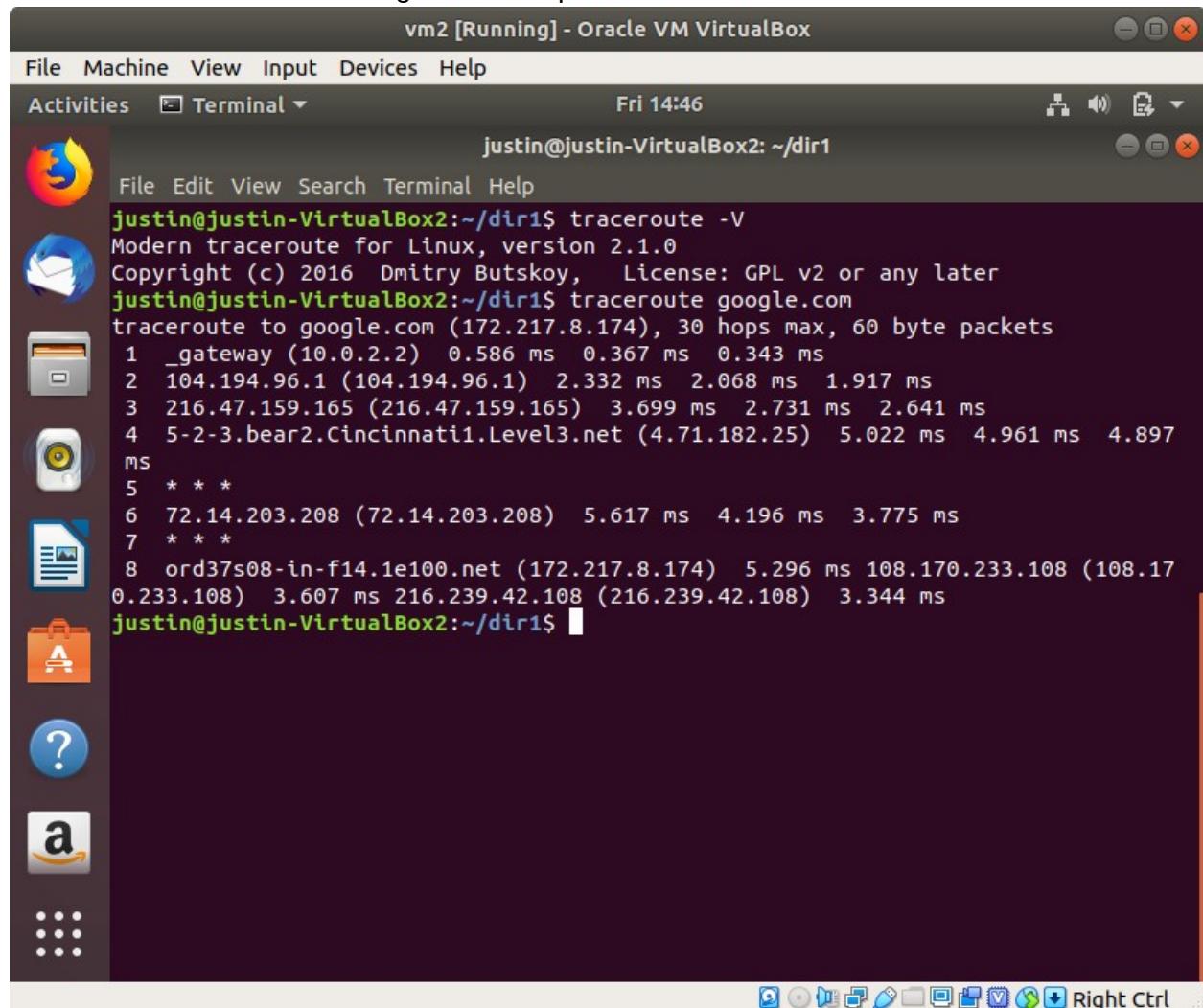
ss. su - Change the current user to another user in the system



tt. ping - Ping a remote host, and show latency statistics



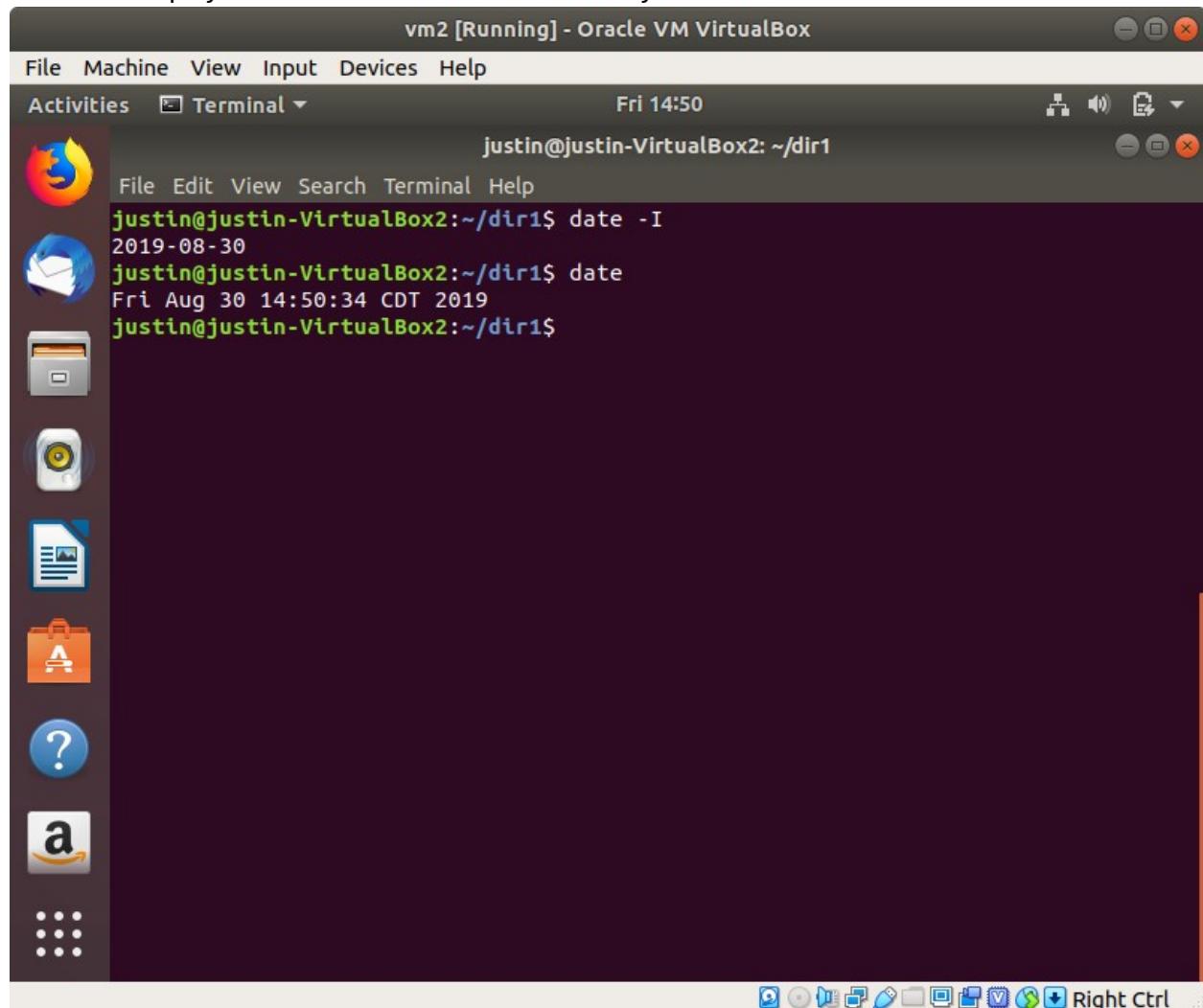
uu. traceroute - trace the routing of the sent packets



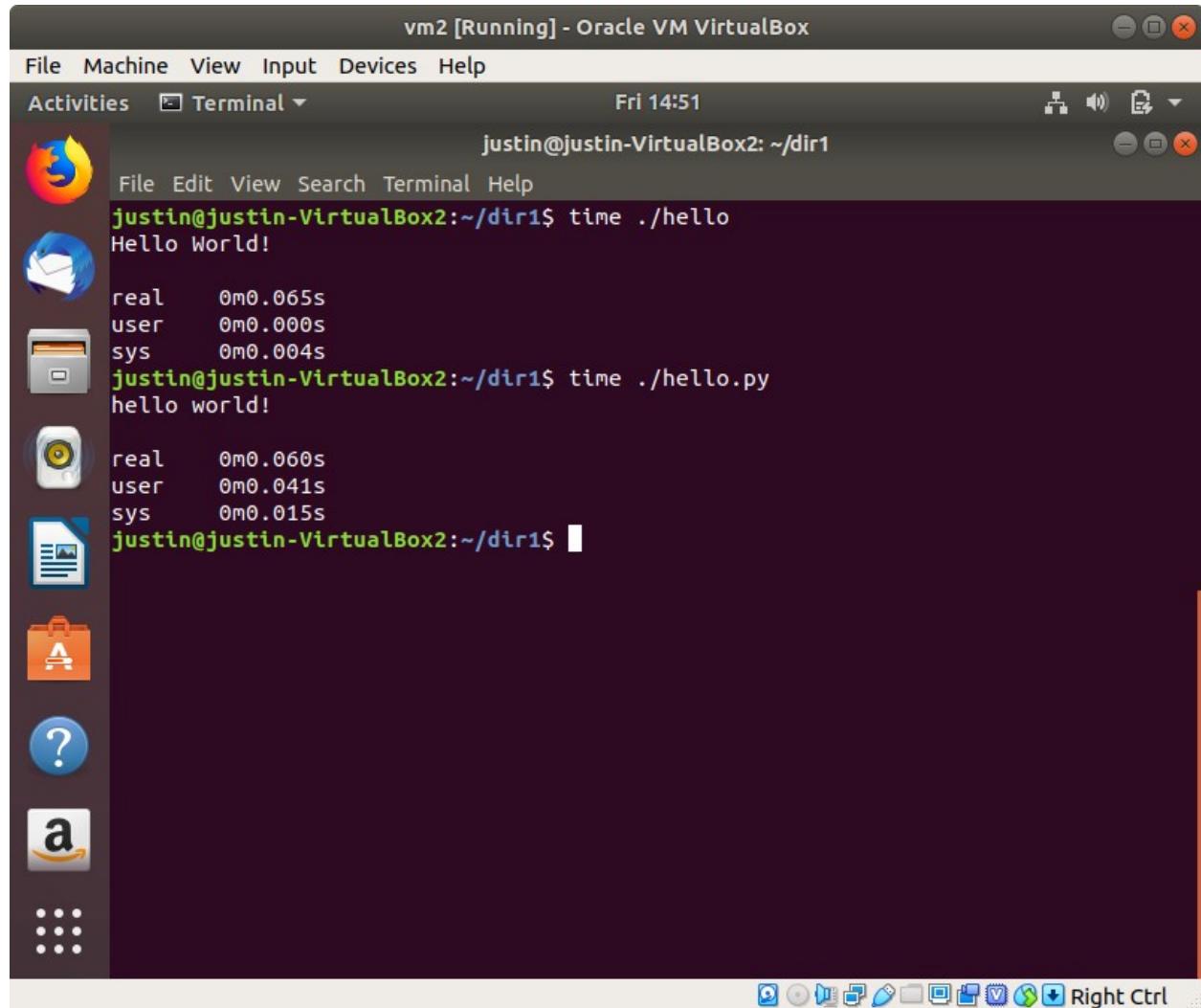
The image shows a screenshot of an Ubuntu desktop environment running inside Oracle VM VirtualBox. The terminal window is titled "vm2 [Running] - Oracle VM VirtualBox". The terminal session shows the user executing the command "traceroute -V" followed by "traceroute google.com". The output of the traceroute command is displayed, showing the path from the user's machine to Google's servers. The desktop interface includes a dock at the bottom with various icons and a system tray with icons for network, battery, and volume.

```
justin@justin-VirtualBox2:~/dir1$ traceroute -V
Modern traceroute for Linux, version 2.1.0
Copyright (c) 2016 Dmitry Butskoy, License: GPL v2 or any later
justin@justin-VirtualBox2:~/dir1$ traceroute google.com
traceroute to google.com (172.217.8.174), 30 hops max, 60 byte packets
 1 _gateway (10.0.2.2)  0.586 ms  0.367 ms  0.343 ms
 2 104.194.96.1 (104.194.96.1)  2.332 ms  2.068 ms  1.917 ms
 3 216.47.159.165 (216.47.159.165)  3.699 ms  2.731 ms  2.641 ms
 4 5-2-3.bear2.Cincinnati1.Level3.net (4.71.182.25)  5.022 ms  4.961 ms  4.897
ms
 5 * * *
 6 72.14.203.208 (72.14.203.208)  5.617 ms  4.196 ms  3.775 ms
 7 * * *
 8 ord37s08-in-f14.1e100.net (172.217.8.174)  5.296 ms 108.170.233.108 (108.17
0.233.108)  3.607 ms 216.239.42.108 (216.239.42.108)  3.344 ms
justin@justin-VirtualBox2:~/dir1$
```

vv. date - display the current date and time of the system



ww. time - show the execution time of a program (Real - start to finish, user - user-mode time, sys - kernel-mode time)

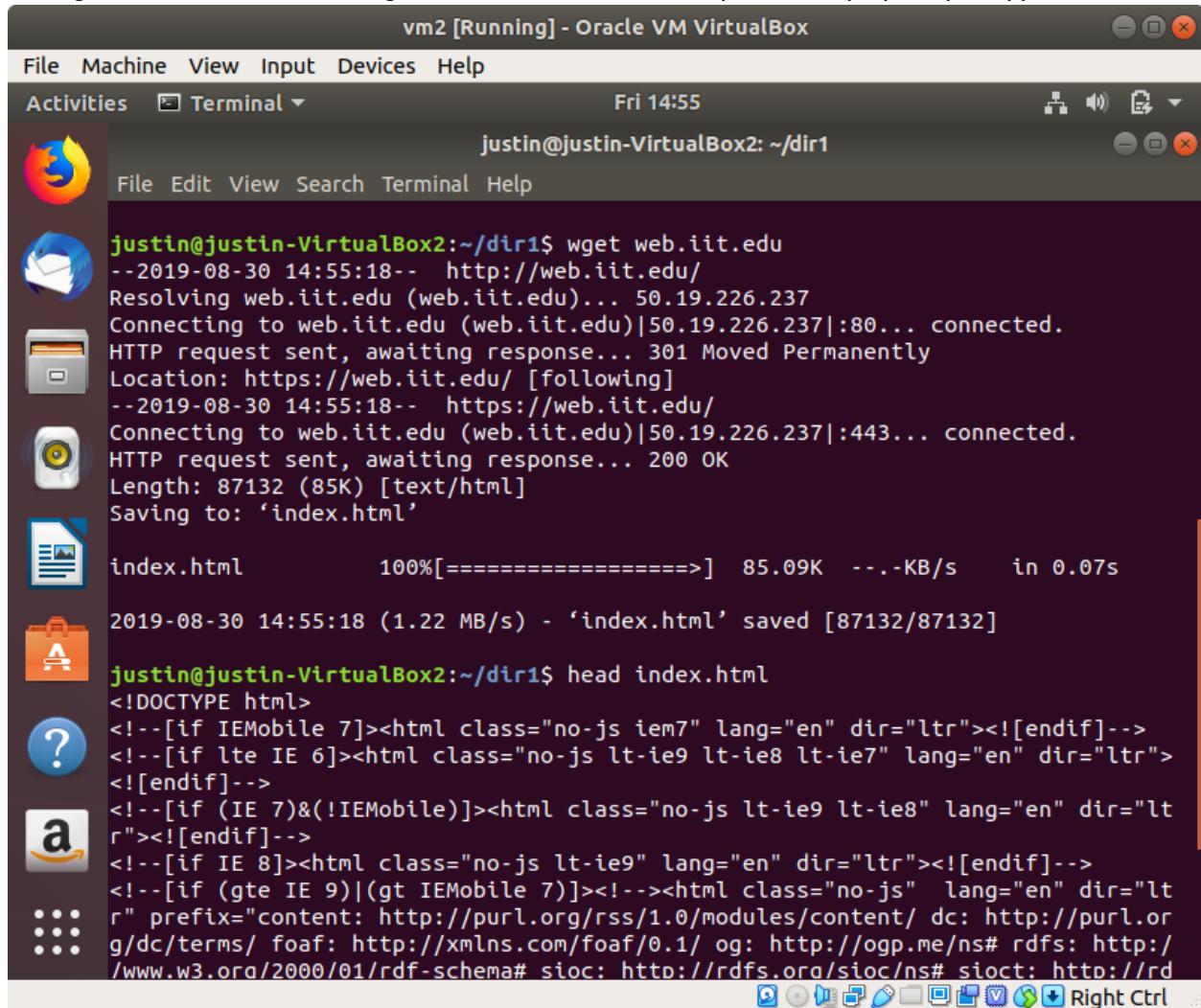


The screenshot shows a Linux desktop environment with a terminal window open. The terminal window is titled "vm2 [Running] - Oracle VM VirtualBox". The desktop interface includes a docked application menu on the left and a dock at the bottom.

Terminal Output:

```
justin@justin-VirtualBox2:~/dir1$ time ./hello
Hello World!
real    0m0.065s
user    0m0.000s
sys     0m0.004s
justin@justin-VirtualBox2:~/dir1$ time ./hello.py
hello world!
real    0m0.060s
user    0m0.041s
sys     0m0.015s
justin@justin-VirtualBox2:~/dir1$
```

xx. wget - download a file using standard communication protocols (http, https, ftp)



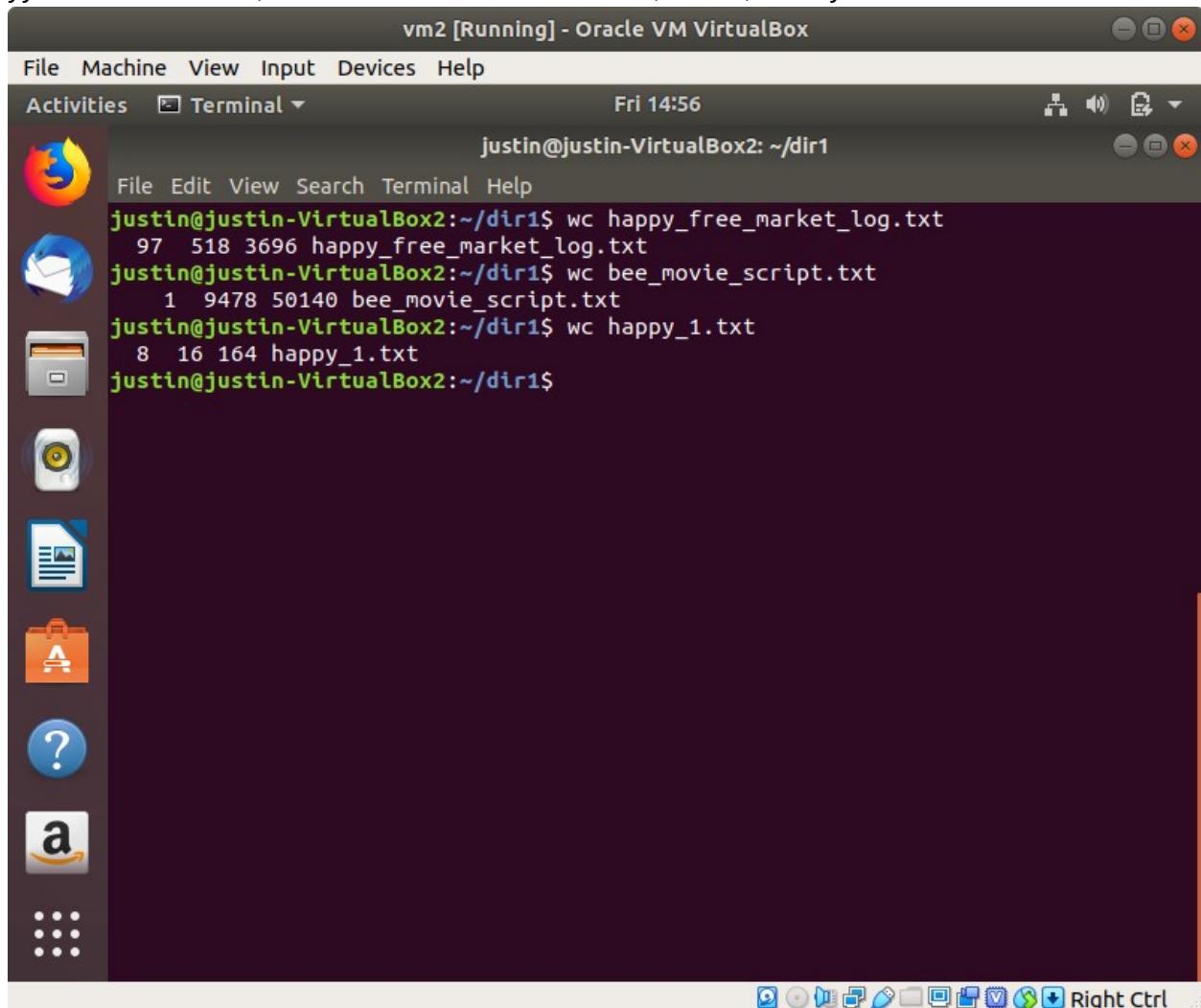
```
justin@justin-VirtualBox2:~/dir1$ wget web.iit.edu
--2019-08-30 14:55:18-- http://web.iit.edu/
Resolving web.iit.edu (web.iit.edu)... 50.19.226.237
Connecting to web.iit.edu (web.iit.edu)|50.19.226.237|:80... connected.
HTTP request sent, awaiting response... 301 Moved Permanently
Location: https://web.iit.edu/ [following]
--2019-08-30 14:55:18-- https://web.iit.edu/
Connecting to web.iit.edu (web.iit.edu)|50.19.226.237|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 87132 (85K) [text/html]
Saving to: 'index.html'

index.html          100%[=====] 85.09K  ---KB/s   in 0.07s

2019-08-30 14:55:18 (1.22 MB/s) - 'index.html' saved [87132/87132]

justin@justin-VirtualBox2:~/dir1$ head index.html
<!DOCTYPE html>
<!--[if IEMobile 7]><html class="no-js iem7" lang="en" dir="ltr"><![endif]-->
<!--[if lte IE 6]><html class="no-js lt-ie9 lt-ie8 lt-ie7" lang="en" dir="ltr">
<![endif]-->
<!--[if (IE 7)&(!IEMobile)]><html class="no-js lt-ie9 lt-ie8" lang="en" dir="lt
r"><![endif]-->
<!--[if IE 8]><html class="no-js lt-ie9" lang="en" dir="ltr"><![endif]-->
<!--[if (gte IE 9)|(gt IEMobile 7)]><!--><html class="no-js" lang="en" dir="lt
r" prefix="content: http://purl.org/rss/1.0/modules/content/ dc: http://purl.or
g/dc/terms/ foaf: http://xmlns.com/foaf/0.1/ og: http://ogp.me/ns# rdfs: http://
www.w3.org/2000/01/rdf-schema# sioc: http://rdfs.org/sioc/ns# sioc: http://rd
```

yy. wc - word count, counts the number of newlines, words, and bytes in a file



The image shows a screenshot of an Ubuntu desktop environment running inside Oracle VM VirtualBox. The desktop has a dark purple background. On the left, there's a vertical dock with icons for various applications: Firefox, Evolution (mail), Nautilus (file manager), Dash (search), Help, and Amazon. The main workspace contains a terminal window titled "vm2 [Running] - Oracle VM VirtualBox". The terminal shows the user's command-line session:

```
justin@justin-VirtualBox2: ~/dir1
justin@justin-VirtualBox2:~/dir1$ wc happy_free_market_log.txt
 97 518 3696 happy_free_market_log.txt
justin@justin-VirtualBox2:~/dir1$ wc bee_movie_script.txt
 1 9478 50140 bee_movie_script.txt
justin@justin-VirtualBox2:~/dir1$ wc happy_1.txt
 8 16 164 happy_1.txt
justin@justin-VirtualBox2:~/dir1$
```

The terminal window has a dark theme with light-colored text. The status bar at the bottom of the window shows various icons for system functions like network, volume, and brightness control.

zz. pwgen - generate pronounceable passwords

```
justin@LT480: ~
File Edit View Search Terminal Help
(base) justin@LT480:~$ pwgen -s -y -v
h=8kCB&S {*Fs6hph z+HF97`g $3(ls>5P /D-:X4(t hT&Fbr9- ;p'9s`W7 ?X7#HZPP
$;_T5x2_ _\SF84L, Z#zZ<;7> .=c!j4wB &R69bMf} ?R^D[5pr )fJz.d4B ;!5m=`<Q
2w]mHqLB (& ,]8tB w4Td&p?m Nd9W3ZF' ;4L'f^'B *WV2^CHf PsX^r42J 3~D)w+-+
DJ5D("x> -2TMRKgp =l5\VRFs XGXB]8H; <hR>t3$B L[3`\Tnm +3$>+Q)m ]42L7F$<
M#f8J]D" /{D8C(P? }>$67)D, f[B)f'N9 k5]`$G3] qL4d-!/< Jmp/}5gS Ztr8;Ck~
4'Q.&g9^ >}L~q4j$ ;`2TB#{t *fSzH`m6 3gwQgL,, c&d3xGDm F-qq;94S %PK635zw
3z[,:_M, "w-k`~8L b'kDD~^5 x2bc"CnX -.7*B}FS **"$6B'j >7.~BQ3> Rc[*^L9w
pJZ~9wWR 3-gR[wM- tXc\ Cf9% m4-k:DHG cvqR('4t nd+d6(WP <KGK*5(\ <ZV9p~dZ
9BG{&|$, Mt;|DH*2 xGF.Zsw8 b-f8Sq<l ]rr8H6>" 4]_{sJ99 w^+_`*X6 d=F:354d
}4@bHjN- pR{>S49B BQ#T8,'t dH&d8f~x 2l6QgL`r D7>?dLz& Hk'c"J7k :8GC~SrH
mj~9p]'H vR5:DMRF lg6*WLJ- vF8C|R*N S2j86/h( qSzM/2T- 9Gs'2[~j c7:^B|v<
Gj5/\]]` |9^ddLpM J-kjxb;2 ;(tN.>9x &!k6Rw|$ ."L7j([c ~]6![!Mr R*"N2+)(
j- "KRM?9 :N/2d; ` - =?fNw{2: qGCSR9<r q2Bx.'`b vhDb,5Q= 2N!`w.Wc 5wf7C'nX
f]/>~5)G mnG7~|,f sn4Q;>{} PvMfRm3* 2!)^GDGc N`}{>>3^ l,+NzN95 @X8R[PT=
Wx$V$Q5h 7w?"HwX# CJpp~p(5 2W- "[]Mx $=9L<*Rj :wR6@=zd bNhR8K=S ~}[?!F9;
mt8P/G{J %s~N5mLQ 2NPqsz:& X/>[@=C5 <<Jp`l2+ PD&j^Pl3 nz74R%z) }tM4r&` .
L(pLqS$6 RpXx6@SM \2@l[|BB Sp29;mD: -<c49`SG /k}v8c=P 6!'S6*4~ mIM"_9_8
$Mq})N69 KB$r>9J' pw:3@T.3 ]/4NBXkP 'f5M]\", BN=9~:Cq 2!GrZ898 f23\@P/!
b-2fT[S* }#F52_q( ~6=8XH3_ s.sg?P!6 KxJwp'3# 3jL#Z[PD r)J98Wjk &FRt@6J)
K]\R4vHw FLv'rqr4 BGM:4P\c ;Bk73Hvr $2~s!j3Z xfS7v3h" #!3qPsDq Mjq#{7m3
(base) justin@LT480:~$ pwgen -s -y -v -N1
gQ-.%),2
(base) justin@LT480:~$
```

Q3a results from the terminal

```
(base) justin@LT480:~/team-25/hw1/src$ time ./generate-dataset.sh file1.txt 10000
File created, filename - "file1.txt" - (10000)
```

```
real 0m8.445s
user 0m6.994s
sys 0m1.993s
```

```
(base) justin@LT480:~/team-25/hw1/src$ time ./generate-dataset.sh file1.txt 100000
File created, filename - "file1.txt" - (100000)
```

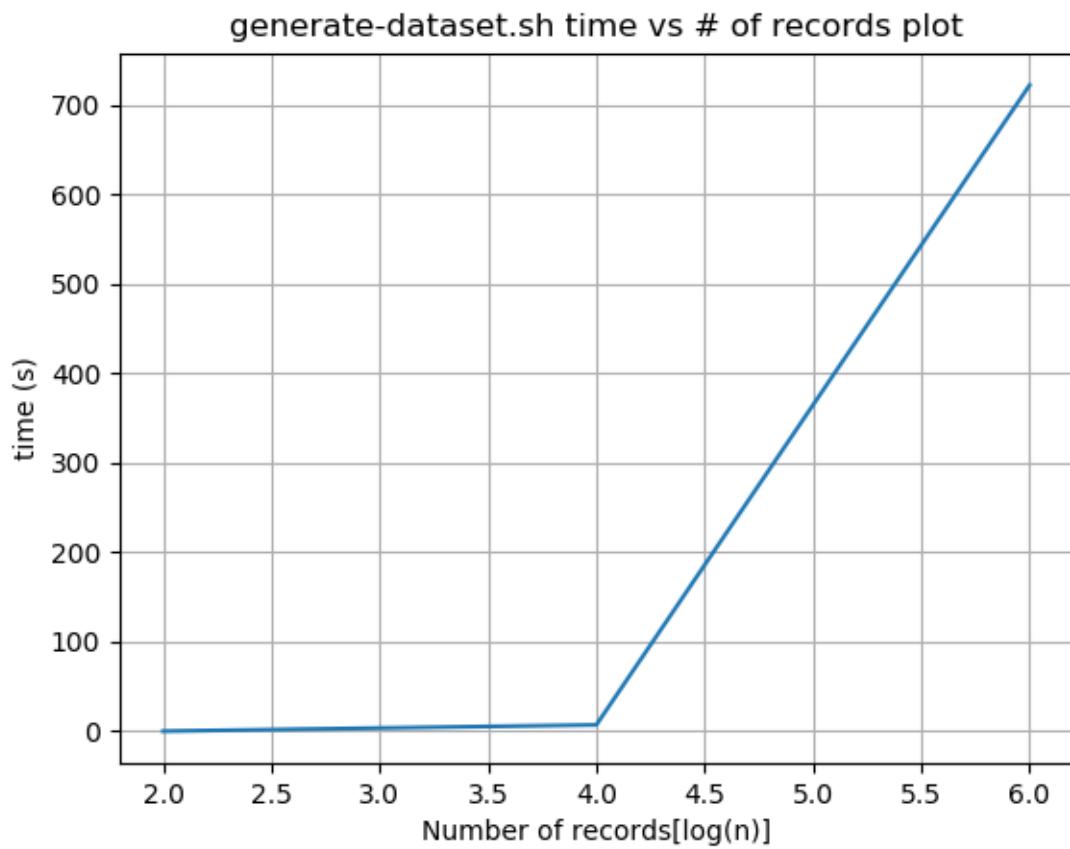
```
real 1m31.469s
user 1m14.306s
sys 0m22.889s
```

```
(base) justin@LT480:~/team-25/hw1/src$ wc file1.txt
100000 300000 12165111 file1.txt
```

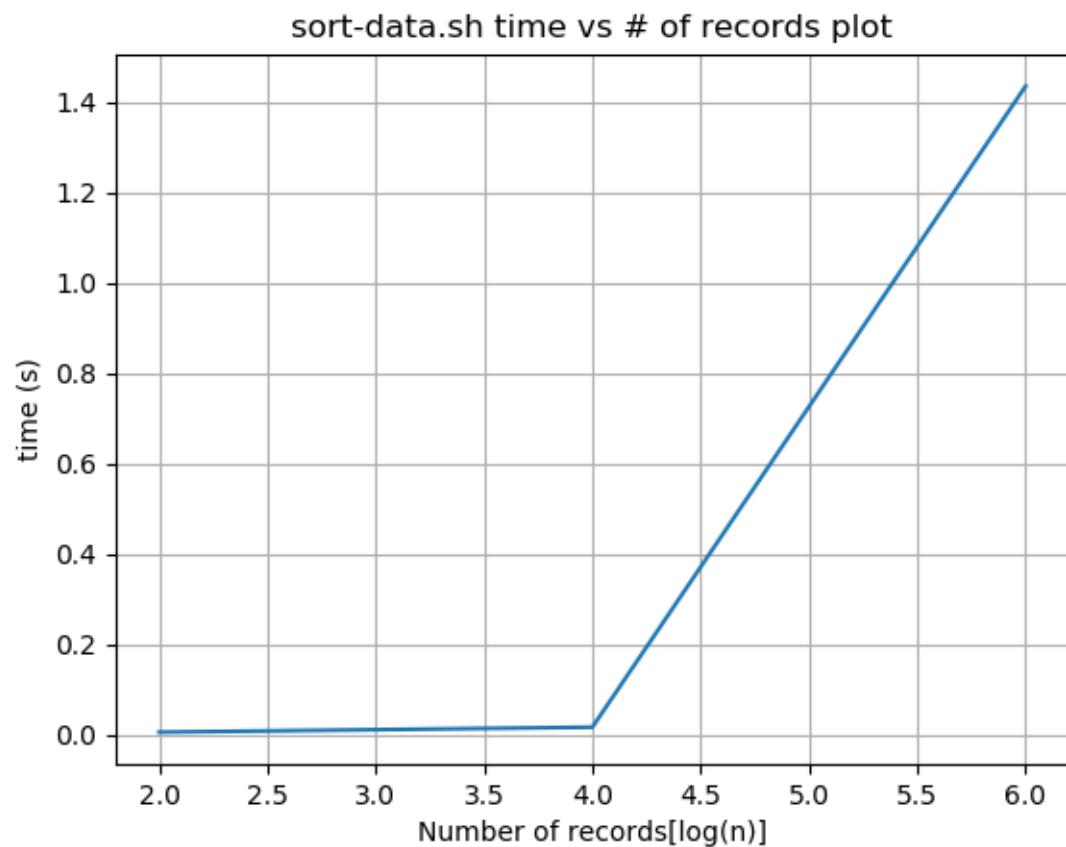
```
(base) justin@LT480:~/team-25/hw1/src$ tail -n 5 file1.txt
972229588 76301292
5u3GtvI6GMKS4FmJyKlfVNHtbzFZRswomlu7xXNNZguZtwlvR5LjrihwLyI3jTFB MtWLgNPzvnEE
lhvceJHSjdd8rC69szCMJ1W4
85006687 833714007
mZQd1asRzbKGK24zEaOcLhIHBOIPRe4aAPI13AsUYWfiltUFfuYcFhlde6D5G4j52L9xpNX7Rh
yuFeMrIZ6pW3EPtP8GjEKAnXJY
2922710006 1646520436
iNoVZlwSn1TIK1eGSTdMj2TB5lnYwvaCAry96FiPAX31Wc2xSBU5R8fm96p64EyGY27tYDj5lcv
oXD6F8UbwUp9UX4ByEWb5W8of
114834580 1695610962
cETe6IraGTG9j05IJ35bpRMXz9uyLo7lOdfz06tVN4FOYAr6o8viFydljTvfKiumImGSuC6Vrj4ESe
WXNbRSDoUM8GA51Lu9S80V
41830450 1182126752
si1P2a7No51xL2NqjN30fJmwqTYwRmTOL9jZNJIYZX5W8NJ5ZUSs1Adu5cMDVHYkB9A7YXr
69zcWfdiHAbQZfWQwStK9urUwQjtN
```

Q3c

Plot for generate-dataset.sh:



Plot for sort-data.sh:



4. (15 points) Answer the following questions about VMs:

a. In the system configuration of the VM, explain how changing the number of processors changes the behavior of your VM. Explain a scenario where you want to set this to the minimum, and a scenario where you want to set it to the maximum. Why is setting it to the maximum potentially a bad idea?

We can change the number of processors we want to assign for the VM. Giving different number of processors will affect the computing ability of VM. In general, more processors brings higher performance. However, setting the number of processors to maximum will sometimes decrease the overall performance of both VM and the computer due to the fact that the host operating system won't have enough computing resources to perform background tasks. Therefore, to decide how many processors we should give to VM, we should think about what kind of tasks we expect the VM do. If we just want to use some desktop applications or run some simple programs. We can simply set the number of processors to the minimum. On the other hand, if we expect the VM to video encoding or run a huge data model, we can consider to raise the number of processors to the maximum.

b. In the system configuration of the VM, under the Acceleration Tab, explain the difference between the paravirtualization options: None, Legacy, Minimal, Hyper-V, and KVM. Explain which one would be best to use with Ubuntu Linux, and why.

None: Specifying none explicitly turns off exposing any paravirtualization interface.

Legacy: The legacy option is chosen for VMs which were created with older VirtualBox versions and will pick a paravirtualization interface while starting the VM with VirtualBox 5.0 and newer.

Minimal: Announces the presence of a virtualized environment. Additionally, reports the TSC and APIC frequency to the guest operating system. This provider is mandatory for running any Mac OS X guests.

KVM: Presents a Linux KVM hypervisor interface which is recognized by Linux kernels starting with version 2.6.25. VirtualBox's implementation currently supports paravirtualized clocks and SMP spinlocks. This provider is recommended for Linux guests.

Hyper-V: Presents a Microsoft Hyper-V hypervisor interface which is recognized by Windows 7 and newer operating systems. VirtualBox's implementation currently supports paravirtualized clocks, APIC frequency reporting, guest debugging, guest crash reporting and relaxed timer checks. This provider is recommended for Windows guests.

We should use KVM for our Ubuntu because it is recognized by Linux kernels and it is recommended for Linux guests.

c. In storage devices when configuring the VM, there are multiple types of storage controllers:

explain the difference between the IDE, SATA, and NVMe controller. Give an example for each type of storage controller of a scenario where you may want to use this type of controller.

IDE: IDE (ATA) controllers are a backwards-compatible yet very advanced extension of the disk controller in the IBM PC/AT (1984). Initially, this interface worked only with hard disks, but was later extended to also support CD-ROM drives and other types of removable media. In physical PCs, this standard uses flat ribbon parallel cables with 40 or 80 wires. Each such cable can connect two devices to a controller, which have traditionally been called master and slave. Typical PCs had two connectors for such cables. As a result, support for up to four IDE devices was most common.

SATA: Serial ATA (SATA) is a more recent standard than IDE. Compared to IDE, it supports both much higher speeds and more devices per controller. Also, with physical hardware, devices can be added and removed while the system is running. The standard interface for SATA controllers is called Advanced Host Controller Interface (AHCI).

NVMe: Non volatile memory express (NVMe) is a standard for connecting non volatile memory (NVM) directly over PCI Express to lift the bandwidth limitation of the previously used SATA protocol for solid-state devices. Unlike other standards the command set is very simple in order to achieve maximum throughput and is not compatible with ATA or SCSI. OSes need to support NVMe devices to make use of them.

Based on the document of VirtualBox, it suggests to avoid IDE unless it is the only controller supported by your guest. Moreover, after I did some research, NVMe seems cause some problems when your using it in some OSes. Since that storage controllers are just virtual controllers so it won't actually affect the performance of the guest too much(we don't need to choose NVMe controller if host is running on NVMe SSD). In other words, unlike a physical NVMe, choosing a virtual NVMe controller won't actually brings you much benefit. Therefore, I suggest to use SATA in general cases.

d. In the network configuration of the VM, there are multiple types of network adapters: explain the difference between NAT, Bridged Adapter, Internal Network, and Host-only Network. Give an example for each type of network of a scenario where you may want to use this type of network.

NAT: Network Address Translation (NAT) is the simplest way of accessing an external network from a virtual machine. Usually, it does not require any configuration on the host network and guest system. For this reason, it is the default networking mode in Oracle VM VirtualBox.

A virtual machine with NAT enabled acts much like a real computer that connects to the Internet through a router. The router, in this case, is the Oracle VM VirtualBox networking engine, which maps traffic from and to the virtual machine transparently. In Oracle VM VirtualBox this router is

placed between each virtual machine and the host. This separation maximizes security since by default virtual machines cannot talk to each other. **Choose this if all you want is to browse the Web, download files, and view email inside the guest.**

Bridged Adapter: This is for more advanced networking needs, such as network simulations and running servers in a guest. When enabled, Oracle VM VirtualBox connects to one of your installed network cards and exchanges network packets directly, circumventing your host operating system's network stack. **Choose this if you want your VM be visible to the outside world and host. For example, build a server in VM.**

Internal Network: This can be used to create a different kind of software-based network which is visible to selected virtual machines, but not to applications running on the host or to the outside world. Internal Networking is 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. **Choose this for security concern. For example, you prefer two or more VMs on the same machine to communicate privately, hiding their data from both the host system and the user,**

Host-only Network: This can be used to create a network containing the host and a set of virtual machines, without the need for the host's physical network interface. Instead, a virtual network interface, similar to a loopback interface, is created on the host, providing connectivity among virtual machines and the host. **Host-only networking is particularly useful for preconfigured virtual appliances, where multiple virtual machines are shipped together and designed to cooperate. For example, one virtual machine may contain a web server and a second one a database, and since they are intended to talk to each other, the appliance can instruct Oracle VM VirtualBox to set up a host-only network for the two. A second, bridged, network would then connect the web server to the outside world to serve data to, but the outside world cannot connect to the database.**

e. For the USB configuration of the VM, explain the difference between USB 1.1, 2.0, and 3.0 controllers.

USB 1.1: OHCI

USB 2.0: EHCI + OHCI

USB 3.0: This supports all USB speeds.

5. (20 points) Answer the following questions about computer processors:

- a. Describe what a core and hardware thread is on a modern processor, and the difference between them?

A CPU core is a hardware component that has a dedicated set of registers, arithmetical logical unit(s), addressing unit and a control unit that can execute instructions, manipulate data in memory and handle interrupts.

A hardware thread is a technique that allows CPU vendors to connect multiple instruction and data pipelines to a single core, providing additional sets of registers that allows the core to switch between the pipelines without offloading state to main memory, thus increasing performance of IO intensive applications. They may be exposed to the operating system and programmers as appearing to be additional cores.

- b. How many cores do the fastest processors from each manufacturer have? Give an example (specific model, specs, and price).

- (a) Intel CPU (x86)

<https://ark.intel.com/content/www/us/en/ark/products/194146/intel-xeon-platinum-9282-processor-77m-cache-2-60-ghz.html>

Intel Xeon Platinum 9282 Processor

Launch Date: Q2'19

Lithography: 14nm

of Cores: 56

of Threads: 112

Processor Base Frequency: 2.60Ghz

Max Turbo Frequency: 3.80Ghz

Cache: 77MB

TDP: 400W

"Prices for these models will not be made public since the processors are BGA-only and will be sold directly to select OEMs in 2U quad-blade configurations. These new server blades will start shipping in Q2 2019."

<https://www.notebookcheck.net/Intel-presents-new-56-core-Xeon-Platinum-server-grade-CPPUs.415676.0.html>

(b) AMD CPU (x86)

<https://www.amd.com/en/products/cpu/amd-epyc-7742>

AMD EPYC 7742

Launch Date: Q2'19

of Cores: 64

of Threads: 128

Processor Base Frequency: 2.25Ghz

Max Turbo Frequency: 3.40Ghz

Total L3 Cache: 256MB

TDP: 225W

Price: \$7,522.99 <https://www.newegg.com/amd-epyc-7742-socket-sp3/p/N82E16819113581>

(c) IBM CPU (Power9)

Power9 - instruction set developed by IBM

<https://en.wikichip.org/wiki/ibm/microarchitectures/power9>

<https://en.wikichip.org/wiki/ibm/power/02cy296>

Model: 02CY296

Launch Date: November 2018

of Cores: 22

of Threads: 88

Processor Base Frequency: 2.75Ghz

Max Turbo Frequency: 3.80Ghz

L3: 110MB

TDP: 190W

(d) ThunderX CPU (ARM)

<https://www.marvell.com/documents/6vi7chuyqr17kc25llol/>

ThunderX_CP™ Family of Workload Optimized Compute Processors

of Cores: up to 48

Processor Frequency: up to 2.5Ghz

Cache: 78K-Icache and 32K-D cache per core, 16 MB shared L2 cache

(e) NVIDIA GPU

Nvidia Quadro RTX 8000

GPU Memory 48 GB GDDR6

Memory Interface 384-bit

Memory Bandwidth 672 GB/s

NVIDIA CUDA Cores 4,608

NVIDIA Tensor Cores 576

NVIDIA RT Cores 72

Single-Precision Performance 16.3 TFLOPS

Tensor Performance 130.5 TFLOPS

Price: \$5531.99

<https://www.amazon.com/PNY-VCQRTX8000-PB-NVIDIA-Quadro-Graphic/dp/B07NH3HKG9>

c. Why do we not have processors running at 1THz today (as might have been predicted in the year 2000)?

Increasing clock frequencies lead to a higher thermal loss. Sufficient cooling is required to maintain operational temperatures, otherwise the chip will be damaged and fail. Chips that operate at higher clock frequencies endure higher thermal stress, and would have lower mean time before failure.

Secondly, an increase in clock frequencies implies an increase in voltage, and thus power consumption. In data centers and other intensive environments, power costs is an important factor.

d. Describe Moore's Law. Is it going to go on forever? If not, when will it end? Justify your answer to why it will end and when.

Moore's Law states that the number of transistors that can be packed into a given unit of space will double about every two years. Many experts agree that Moore's Law is coming to an end in 2020s, where manufacturing smaller transistors becomes physically impossible. As transistors are made smaller, eventually it reaches a certain point where quantum tunneling of electrons would render the miniaturized transistors produce inconsistent results and becomes non-functional.

Question 6 :

a. Why is threading useful on a single-core processor?

On a single -core processor, threading allows multiple instructions to be processed at a time.

b. Do more threads always mean better performance?

More threads do not always imply a better performance. If we have too many threads for a simple process, it could take more time. Or if a program is not designed to use multiple threads, having many threads will not improve the performance.

c. Is super-linear speedup possible? Explain why or why not.

Super-linear speedup is possible if the task given is embarrassingly parallelizable. As we split the data into smaller pieces, it is possible that the size of the data becomes small enough such that it fits into higher memory hierarchy component (e.g. from memory → L3 cache, or L3 cache → L2 cache etc), which often times the speeds up comes in chunks. Together with more cores, the speed up is possible to be super-linear.

d. Why are locks needed in a multi-threaded program?

Locks are abstractions provided by the operating systems to coordinate shared resources across threads. They are used to avoid race-conditions in programs. For instance, if two threads increment the same variable, at the end it's not guaranteed that we will have the expected value. To avoid that, we have to use locks to control the access to the variable.

e. Would it make sense to limit the number of threads in a server process?

It makes sense to limit the number of threads in a server process because a processor core can have 2 threads at most normally. Introducing too many threads would incur a high overhead to the system, thus lowering the overall performance.

- End -