Linux Foundation Certified System Administrator (LFCS)

Exam preparation notes

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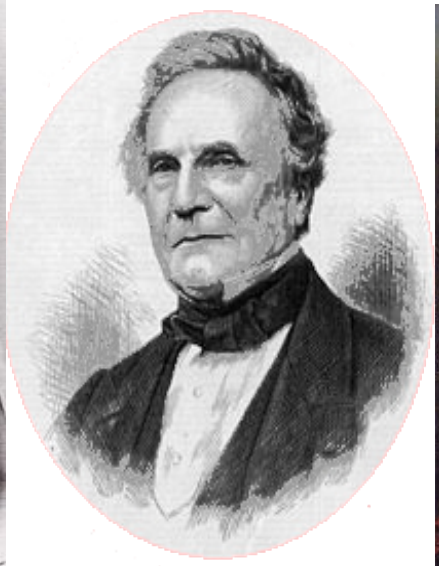
Throughout this document I am ably assisted by Luigi Menabrea, Ada Lovelace and Charles Babbage. All of these individuals were key to the development of the famous analytical engine of 1830s and 40s fame from which modern computing can trace its origins.

Babbage developed the analytical engine after a number of attempts to build a difference engine, made to compute values of polynomial functions. The Analytical Engine is the transition to general purpose computation from mechanised calculators.

Luigi went on to serve as the 7th Prime Minister of Italy from 1867 to 1869. His sketch of “The Analytical Engine” Invented by Charles Babbage, Esq while a military engineer was translated by Ada Augusta, Countess of Lovelace in 1842. These notes included additional detail that Lovelace is now widely recognised as the world's first computer program and therefore Ada is credited as being the first computer programmer.

Luigi Menabrea



Charles Babbage

Ada Lovelace

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The Linux Foundation Certified System Administrator (LFCS) examination is a practical test based on the command line. Familiarity with the GNU/Linux command line is essential in order to pass. Establish a Virtual Machine (VM) that you do not mind “breaking” and work with it. KVM or Oracle VirtualBox are good candidates for this.

1. Local system administration

1.1. Creating backups

This is the process for creating backups using the **gzip** or **bz2** utilities. This are explained in detail in section 3.

Backup the /**home** directory using **gzip**.

```
$ sudo tar -czvf /home.tgz /home

$ file /home.tgz
home.tgz: gzip compressed data, from Unix, last modified: Tue Oct 21 10:38:46
2014
```

Backup the /**home** directory using **bz2**.

```
$ sudo tar -cjvf /home.tbz2 /home

$ file /home.tbz2
home.tbz2: bzip2 compressed data, block size = 900k
```

1.2. Managing local users accounts

Main users account options.

Option	Notes
-c, --comment COMMENT	
-m, --create-home	Create the user's home directory.
-s, --shell SHELL	Login shell of the new account.
-U, --user-group	Create a group with the same name as the user.

Add a user Ada Lovelace to the system.

```
$ sudo useradd -c "Ada Lovelace" -s /bin/bash -m alovelace

$ cat /etc/passwd |grep alovelace
alovelace:x:1002:1002:Ada Lovelace:/home/alovelace:/bin/bash
```

Change the password for Ada Lovelace.

```
$ sudo passwd alovelace
Enter new UNIX password: maths
Retype new UNIX password: maths
passwd: password updated successfully
```

Test the login for Ada Lovelace.

```
$ su alovelace
Password: maths
$ id
uid=1002(alovelace) gid=1002(alovelace) groups=1002(alovelace)
```

1.3. Managing user accounts

Add Ada Lovelace to the **babbage** group.

```
$ sudo usermod -g babbage alovelace
```

1.4. Managing user account attributes

Change the shell of Ada Lovelace to **tcsh**.

```
$ sudo usermod -s /bin/tcsh alovelace

$ cat /etc/passwd | grep alovelace
alovelace:x:1002:1002:Ada Lovelace:/home/alovelace:/bin/tcsh
```

Add Ada Lovelace to the **babbage** group as well as the **alovelace** group.

```
$ cat /etc/group | grep babbage
babbage:x:1003:

$ sudo usermod -a -G alovelace,babbage alovelace

$ cat /etc/group | grep babbage
babbage:x:1003:alovelace
```

1.4.2. Password expiry management

The **chage** command is used to change the number of days between password changes and the date of the last password change.

```
$ sudo passwd alovelace
Enter new UNIX password: maths
Retype new UNIX password: maths
passwd: password updated successfully
```

Review Ada Lovelace's password aging information.

```
$ sudo chage -l alovelace
Last password change                                    : Nov 19, 2014
Password expires                                        : never
Password inactive                                       : never
Account expires                                         : never
Minimum number of days between password change          : 0
Maximum number of days between password change          : 99999
Number of days of warning before password expires       : 7
```

Set Ada Lovelace's account expiration date to 1st December 2014, the minimum number of days before password change to ten and the maximum number of days before password change to twenty.

```
$ sudo chage -E 2014-12-01 -m 10 -M 20 alovelace
```

```
$ sudo chage -l alovelace
Last password change                                    : Nov 19, 2014
Password expires                                        : Dec 09, 2014
Password inactive                                       : never
Account expires                                         : Dec 01, 2014
Minimum number of days between password change          : 10
Maximum number of days between password change          : 20
Number of days of warning before password expires       : 7
```

Setting the date of last password change to zero forces a password change at the next login.

```
$ sudo chage -d 0 alovelace
$ sudo chage -l alovelace
Last password change                                    : password must be changed
Password expires                                        : password must be changed
Password inactive                                       : password must be changed
Account expires                                         : Dec 01, 2014
Minimum number of days between password change          : 10
Maximum number of days between password change          : 20
Number of days of warning before password expires       : 7
```

The following sequence of attempts to change the password gives some idea of the general restrictions.

```
$ su - alovelace
Password:
You are required to change your password immediately (root enforced)
Changing password for alovelace.
(current) UNIX password: maths
Enter new UNIX password: maths
Retype new UNIX password: maths
Password unchanged
Enter new UNIX password: ada
Retype new UNIX password: ada
You must choose a longer password
Enter new UNIX password: ada123
Retype new UNIX password: ada123
Bad: new password is too simple
su: Authentication token manipulation error


$ su - alovelace
Password:
You are required to change your password immediately (root enforced)
Changing password for alovelace.
(current) UNIX password: maths
Enter new UNIX password: multiply
Retype new UNIX password: multiply

alovelace~$ id
uid=1001(alovelace) gid=1001(alovelace) groups=1001(alovelace)

$ sudo chage -l alovelace
Last password change                                    : Nov 19, 2014
Password expires                                        : Dec 09, 2014
Password inactive                                       : never
Account expires                                         : Dec 01, 2014
Minimum number of days between password change          : 10
Maximum number of days between password change          : 20
Number of days of warning before password expires       : 7
```

1.5. Creating local user groups

Create a user group called **babbage**.

```
$ sudo groupadd babbage

$ cat /etc/group |grep babbage
babbage:x:1003:
```

Add a group password for the new group **babbage**.

```
$ sudo gpasswd babbage
Changing the password for group babbage
New Password: engine
Re-enter new password: engine
```

In practice the group password is not that useful. It was conceived to allow a user who does not have access to a particular group could use the **newgrp** command to award such a group access. In this case the group password would be used in response to the system challenge.

1.6. Managing file permissions

Every file and directory on a GNU/Linux system has an owner and a group associated with it. Taking a directory **sandbox** owned by user **lmenabrea** and group **lmenabrea**, change the group to **babbage**.

```
$ ls -la |grep sandbox
drwxr-xr-x  2 lmenabrea lmenabrea    4096 Oct 21 15:48 sandbox

$ sudo chgrp babbage ./sandbox

$ ls -la |grep sandbox
drwxr-xr-x  2 lmenabrea babbage     4096 Oct 21 15:39 sandbox
```

Change the permissions on the directory to give the group Read, Write and eXecute (RWX) permissions.

```
$ chmod g+w sandbox     or     $ chmod 775 sandbox

$ ls -la | grep sandbox
drwxrwxr-x  2 lmenabrea babbage     4096 Oct 21 15:39 sandbox
```

Create two files, one owned by Luigi Menabrea and the other by Ata Lovelace in the **sandbox** directory.

```
$ echo "This is a Luigi Menabrea file." > file1.txt
$ su alovelace
Password: maths
sandbox> echo "This is an Ata Lovelace file." > file2.txt
sandbox> exit
```

Review the file in the **sandbox** directory.

```
$ ls -la
total 16
drwxrwxr-x 2 lmenabrea  babbage   4096 Oct 21 15:55 .
drwxr-xr-x 6 lmenabrea  lmenabrea  4096 Oct 21 15:50 ..
-rw-r--r-- 1 lmenabrea  lmenabrea    34 Oct 21 15:54 file1.txt
-rw-rw-r-- 1 alovelace alovelace   30 Oct 21 15:55 file2.txt

$ cat file1.txt
This is a Luigi Menabrea file.

$ cat file2.txt
This is an Ata Lovelace file.
```

Why can Ata Lovelace write in the directory ? Well she is part of the **babbage** group and as the directory has RW permissions for the **babbage** group she has rights to Read and Write files.

1.6.1. Change file attributes

The **chattr** command permits the changing of extended attributes to files on filesystems that support them like ext2, ext3, ext4, XFS and JFS. The corresponding **lsattr** command displays the extended attributes for files.

chattr [-+=AaCcDdeijSsTtu] files

Operators

- '+' - Adds selected attributes
- '-' - Removes selected attributes
- '=' - Specifies that there are the only attributes

Adjustable attributes

- A - no atime updates
- a - append only
- C - no copy on write
- c - compressed
- D - synchronous directory updates
- d - no dump
- e - extent format
- i - immutable (Superuser only)
- j - data journalling
- S - synchronous updates
- s - secure deletion
- T - top of directory hierarchy
- t - no tail-merging
- u - undeletable

Read only attributes

- E - compression error
- h - huge file
- I - indexed directory
- X - compression raw access
- Z - compressed dirty file (Z)

To demonstrate create a directory and a file and review the associated extended attributes. Only **e** is set which indicates that the file is using extents for mapping the blocks on disk. Remove it and replace it again from the **adafile**.

```
$ mkdir adadirectory
$ touch adafile

$ lsattr
-------------e-- ./adadirectory
-------------e-- ./adafile

$ chattr -e adafile
$ lsattr adafile
---------------- adafile

$ chattr +e adafile
$ lsattr adafile
-------------e-- adafile
```

Now set the immutable attribute on the file. This will prevent deletion or renaming of the file. It will also prevent all but the superuser from writing date to the file. It can only be set with superuser privileges.

```
$ echo "Ada Lovelace file" > adafile
$ cat adafile
Ada Lovelace file

$ sudo chattr +i adafile
[sudo] password for lmenabrea:

$ lsattr adafile
----i--------e-- adafile

$ echo "Change Ada Lovelace" >> adafile
bash: adafile: Permission denied

$ rm adafile
rm: remove write-protected regular file ‘adafile’? yes
rm: cannot remove ‘adafile’: Operation not permitted

$ mv adafile ADAfile
mv: cannot move ‘adafile’ to ‘ADAfile’: Operation not permitted
```

To securely delete a file where its blocks are zeroed and written back to the disk set the **s** attribute.

```
$ sudo chattr =es adafile
$ lsattr adafile
s------------e-- adafile
```

Another interesting attribute is the **A** which tells the filesystem to NOT update the file's **atime**. This cuts down on disk access which is good for extending the life of an Solid State Drive (SSD) or extending the life of a laptop battery. While this can be done with this extended attribute the more typical method is to mount the filesystem with the **noatime** option. Note in the example that once the **A** is set the Access time remains constant.

```
$ stat adafile
  File: 'adafile'
  Size: 86            Blocks: 8          IO Block: 4096   regular file
Device: fc01h/64513d  Inode: 12194930    Links: 1
Access: (0644/-rw-r--r--)  Uid: ( 1000/lmenabrea)   Gid: ( 1000/lmenabrea)
Access: 2014-11-26 06:36:58.176489751 +0000
Modify: 2014-11-26 06:40:13.100481599 +0000
Change: 2014-11-26 06:46:18.964466297 +0000
 Birth: -

$ cat adafile
Ada Lovelace file

$ stat adafile
  File: 'adafile'
  Size: 86            Blocks: 8          IO Block: 4096   regular file
Device: fc01h/64513d  Inode: 12194930    Links: 1
Access: (0644/-rw-r--r--)  Uid: ( 1000/lmenabrea)   Gid: ( 1000/lmenabrea)
Access: 2014-11-26 06:46:43.928465253 +0000
Modify: 2014-11-26 06:40:13.100481599 +0000
Change: 2014-11-26 06:46:18.964466297 +0000
 Birth: -

$ chattr +A adafile

$ cat adafile
Ada Lovelace file

$ stat adafile
  File: 'adafile'
  Size: 86            Blocks: 8          IO Block: 4096   regular file
Device: fc01h/64513d  Inode: 12194930    Links: 1
Access: (0644/-rw-r--r--)  Uid: ( 1000/lmenabrea)   Gid: ( 1000/lmenabrea)
Access: 2014-11-26 06:46:43.928465253 +0000
Modify: 2014-11-26 06:40:13.100481599 +0000
Change: 2014-11-26 06:47:04.464464394 +0000
 Birth: -
```

1.6.2. Access Control Lists

GNU/Linux has the facility to apply Access Control Lists (ACL) to give more granularity to file and directory management.

Here is a directory **sandbox** that is owned by **lmenabrea** and has a group of **babbage**.

```
$ sudo groupadd babbage
$ mkdir sandbox
$ sudo chgrp babbage sandbox

$ ls -la |grep sandbox
drwxrwxr-x  2 lmenabrea babbage  4096 Nov 19 21:05 sandbox
```

The **setfacl** utility is used to set ACLs for files and directories. ACLs can be added or modified using the **-m** switch option. Here are a number of examples. First get the ACL details for the **sandbox** directory using the **getfacl** sister utility.

```
$ getfacl sandbox
# file: sandbox
# owner: lmenabrea
# group: babbage
user::rwx
group::rwx
other::r-x
```

Giving Ada Lovelace read/write privileges to the directory.

```
$ sudo setfacl -m u:alovelace:rw sandbox

$ sudo getfacl sandbox
# file: sandbox
# owner: lmenabrea
# group: babbage
user::rwx
user:alovelace:rw-
group::rwx
mask::rwx
other::r-x
```

Add the **lmenabrea** group with read/write privileges.

```
$ sudo setfacl -m g:lmenabrea:rw sandbox

$ sudo getfacl sandbox
# file: sandbox
# owner: lmenabrea
# group: babbage
user::rwx
user:alovelace:rw-
group::rwx
group:lmenabrea:rw-
mask::rwx
other::r-x
```

Remove the **lmenabrea** group rights with the **-x** switch option.

```
$ setfacl -x g:lmenabrea sandbox

$ sudo getfacl sandbox
# file: sandbox
# owner: lmenabrea
# group: babbage
user::rwx
user:alovelace:rw-
group::rwx
mask::rwx
other::r-x
```

1.7. Managing fstab entries

The file /**etc/fstab** contains descriptive information about the various file systems.

```
$ cat /etc/fstab

# /etc/fstab: static file system information.
#
# Use 'blkid' to print the universally unique identifier for a
# device; this may be used with UUID= as a more robust way to name devices
# that works even if disks are added and removed. See fstab(5).
#
# <file system>           <mount point>   <type> <options>         <dump> <pass>
/dev/mapper/mint--vg-root      /           ext4  errors=remount-ro   0       1
# /boot was on /dev/sda1 during installation
UUID=3b0a7ce9-55c7-43b1-8c54-96510bbda441  /boot   ext2    defaults  0       2
/dev/mapper/mint--vg-swap_1   none        swap    sw                0       0
```

Field	Function	Notes
1	Device name	Use '**dmesg**' or '**lsblk**' to find the device name.
2	Mount point	A directory that exists.
3	File system type	ext2, ext3, ext4, reiserfs, swap, vfat, ntfs, ISP 9660, auto
4	Mount options	auto, noauto, exec, noexec, user, nouser, ro, rw, sync, async, suid, nosuid
5	Dump	0 - exclude from backup, nonzero value - device will be backed up.
6	fsck option	0 - exclude from fsck check, nonzero value - fsck check in order of value.

Default options are: rw,suid,dev,exec,auto,nouser,async

1.8. Restoring backed up data

Restore the **/home** directory using a **gzip** backup.

```
$ cd /
$ sudo tar -xzvf /home.tgz
```

Restore the **/home** directory using a **bz2** backup.

```
$ cd /
$ sudo tar -xjvf /home.tbz2
```

1.9. Setting file permissions and ownership

Create a simple script in the **sandbox**.

```
$ cat << SCRIPT > hello.sh
#!/bin/bash
echo "Hello World"
SCRIPT
```

Make the script eXecutable and execute.

```
$ ls -la | grep hello.sh
-rw-r--r-- 1 lmenabrea  lmenabrea    31 Oct 21 16:05 hello.sh

$ chmod +x hello.sh

$ ls -la | grep hello.sh
-rwxr-xr-x 1 lmenabrea  lmenabrea    31 Oct 21 16:05 hello.sh

$ ./hello.sh
Hello World
```

Remove the eXecute rights from the script.

```
$ chmod -x hello.sh

$ ls -la | grep hello.sh
-rw-r--r-- 1 lmenabrea  lmenabrea    31 Oct 21 16:05 hello.sh
```

Change the group of the script to **babbage** and give it group eXecute permissions.

```
$ sudo chgrp babbage hello.sh

$ ls -la | grep hello.sh
-rw-r--r-- 1 lmenabrea  babbage    31 Oct 21 16:05 hello.sh

$ chmod g+x hello.sh

$ ls -la | grep hello.sh
-rw-r-xr-- 1 lmenabrea  babbage    31 Oct 21 16:05 hello.sh
```

Note that the owner cannot run the script however Ata Lovelace who belongs to the **babbage** group can.

```
$ ./hello.sh
bash: ./hello.sh: Permission denied

$ su alovelace
Password: maths

sandbox> ./hello.sh
Hello World
```

1.10. Managing user processes

Install the package **stress** and run it as Ada Lovelace.

```
$ sudo apt-get install stress

$ su alovelace
Password: maths

sandbox> stress --cpu 3
stress: info: [4939] dispatching hogs: 3 cpu, 0 io, 0 vm, 0 hdd
```

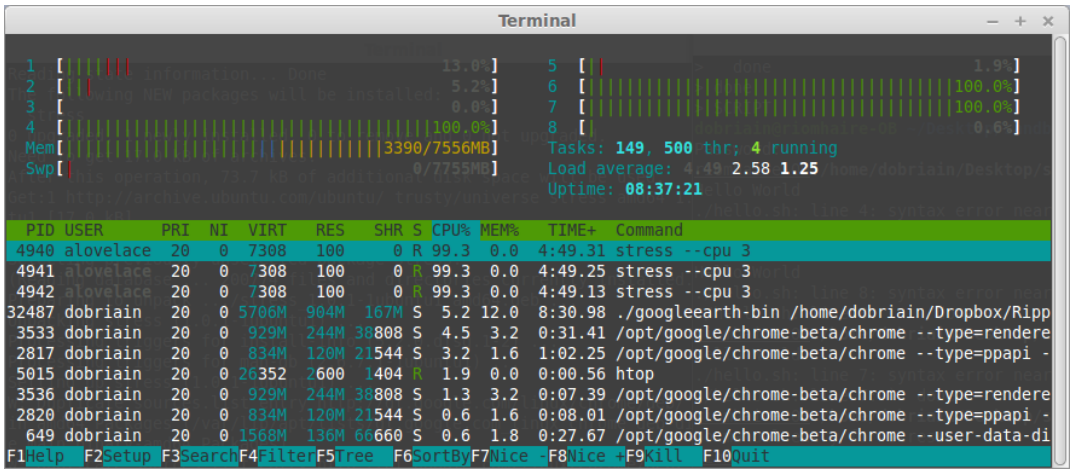
1.10.1. top/htop

Monitor processes using **top**.

```
$ top

top - 17:02:24 up  8:34,  4 users,  load average: 2.83, 1.07, 0.57
Tasks: 285 total,   5 running, 280 sleeping,   0 stopped,   0 zombie
%Cpu(s):  2.0 us,  0.6 sy,  0.1 ni, 96.5 id,  0.6 wa,  0.2 hi,  0.0 si,  0.0 st
KiB Mem:   7738224 total,  7360264 used,   377960 free,   195104 buffers
KiB Swap:  7942140 total,      628 used,  7941512 free.  3712256 cached Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU %MEM     TIME+ COMMAND
 4940 alovela+  20   0    7308    100      0 R  95.0  0.0   1:34.62 stress
 4941 alovela+  20   0    7308    100      0 R  95.0  0.0   1:34.56 stress
 4942 alovela+  20   0    7308    100      0 R  95.0  0.0   1:34.60 stress
 2817 lmenabrea  20   0  846300 116420  14880 S   6.3  1.5   0:58.97 chrome
    1 root      20   0   34024   3328   1496 S   0.0  0.0   0:01.92 init
    2 root      20   0       0      0      0 S   0.0  0.0   0:00.01 kthreadd
    3 root      20   0       0      0      0 S   0.0  0.0   0:00.22 ksoftirqd/0
    5 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kworker/0:0H
    7 root      20   0       0      0      0 S   0.0  0.0   0:19.93 rcu_sched
    8 root      20   0       0      0      0 S   0.0  0.0   0:03.87 rcuos/0
```

htop command is an improved top. It typically needs to be installed.

```
$ sudo apt-get install htop

$ htop
```



1.10.2. Process Snapshot (ps)

Review the processes, focusing on the **stress** process started by Ada Lovelace.

```
$ ps -A | grep stress
 4939 pts/2    00:00:00 stress
 4940 pts/2    00:07:42 stress
 4941 pts/2    00:07:42 stress
 4942 pts/2    00:07:42 stress

$ ps aux | grep stress
alovela+  4939  0.0  0.0   7308   432 pts/2    S+   17:00   0:00 stress --cpu 3
alovela+  4940 99.7  0.0   7308   100 pts/2    R+   17:00   8:03 stress --cpu 3
alovela+  4941 99.7  0.0   7308   100 pts/2    R+   17:00   8:03 stress --cpu 3
alovela+  4942 99.7  0.0   7308   100 pts/2    R+   17:00   8:03 stress --cpu 3
lmenabrea  5128  0.0  0.0  11744   912 pts/5    S+   17:08   0:00 grep
--colour=auto stress

$ ps -ef | grep stress
alovela+  4939  4225  0 17:00 pts/2    00:00:00 stress --cpu 3
alovela+  4940  4939 99 17:00 pts/2    00:08:10 stress --cpu 3
alovela+  4941  4939 99 17:00 pts/2    00:08:10 stress --cpu 3
alovela+  4942  4939 99 17:00 pts/2    00:08:10 stress --cpu 3
lmenabrea  5131  4256  0 17:08 pts/5    00:00:00 grep --colour=auto stress
```

1.10.3. kill processes

Individual processes can be stopped using the **kill** command with the **-9** switch.

```
$ pgrep stress
5224
5225
5226
5257
5258
5259
5260
```

```
$ sudo kill -9 5224

$ pgrep stress
5225
5226
5257
5258
5259
5260
```

To kill all process any of the following options will do.

```
$ sudo kill $(pgrep stress)
$ sudo pkill stress
$ sudo killall stress

$ pgrep stress
```

1.10.4. nice/renice

nice is a utility for managing scheduling priority of processes. Nice values range from -19 (very high priority) to 19 (very low priority) with a value of 0 being the default priority. Looking at the **top** output, the column marked **NI** indicated the current nice value of each process.

```
$ top

top - 17:28:33 up  9:00,  3 users,  load average: 2.84, 2.83, 2.63
Tasks: 280 total,   6 running, 274 sleeping,   0 stopped,   0 zombie
%Cpu(s):  3.5 us,  0.6 sy,  0.1 ni, 94.9 id,  0.6 wa,  0.2 hi,  0.0 si,  0.0 st
KiB Mem:   7738224 total,  7536796 used,   201428 free,   169464 buffers
KiB Swap:  7942140 total,      648 used,  7941492 free.  3705332 cached Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU %MEM     TIME+ COMMAND
 5640 alovela+  20   0    7308    100      0 R  84.4  0.0   0:06.04 stress
 5642 alovela+  20   0    7308    100      0 R  84.4  0.0   0:06.03 stress
 5641 alovela+  20   0    7308    100      0 R  79.1  0.0   0:06.04 stress
 5643 alovela+  20   0    7308    100      0 R  79.1  0.0   0:06.04 stress
 2817 lmenabrea  20   0  846300 113908  13676 S   5.3  1.5   1:33.87 chrome
 3533 lmenabrea  20   0 1086508 395052  39320 S   5.3  5.1   1:42.02 chrome
```

Change the nice value of the **stress** processes by lowering it to 15.

```
$ sudo renice 15 5640
5640 (process ID) old priority 0, new priority 15

$ top

top - 17:29:31 up  9:01,  3 users,  load average: 3.83, 3.12, 2.75
Tasks: 280 total,   7 running, 273 sleeping,   0 stopped,   0 zombie
%Cpu(s):  3.6 us,  0.6 sy,  0.2 ni, 94.8 id,  0.6 wa,  0.2 hi,  0.0 si,  0.0 st
KiB Mem:   7738224 total,  7561620 used,   176604 free,   173632 buffers
KiB Swap:  7942140 total,      648 used,  7941492 free.  3718144 cached Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU %MEM     TIME+ COMMAND
 5640 alovela+  35  15    7308    100      0 R  99.7  0.0   1:03.97 stress
 5641 alovela+  20   0    7308    100      0 R  99.7  0.0   1:03.96 stress
 5642 alovela+  20   0    7308    100      0 R  99.7  0.0   1:03.92 stress
 5643 alovela+  20   0    7308    100      0 R  99.7  0.0   1:03.97 stress
 3533 lmenabrea  20   0 1094700 402600  39320 S   6.2  5.2   1:45.17 chrome
```

Change all Ada Lovelaces processes to a nice value of **-5**.

```
$ sudo renice -5 -u alovelace
1002 (user ID) old priority 0, new priority -5

top - 17:30:58 up  9:02,  3 users,  load average: 4.35, 3.46, 2.90
Tasks: 281 total,   5 running, 276 sleeping,   0 stopped,   0 zombie
%Cpu(s):  3.7 us,  0.6 sy,  0.2 ni, 94.7 id,  0.6 wa,  0.2 hi,  0.0 si,  0.0 st
KiB Mem:   7738224 total,  7518100 used,   220124 free,   156512 buffers
KiB Swap:  7942140 total,      648 used,  7941492 free.  3691376 cached Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU %MEM     TIME+ COMMAND
 5641 alovela+  15  -5    7308    100      0 R 100.0  0.0   2:30.70 stress
 5642 alovela+  15  -5    7308    100      0 R 100.0  0.0   2:30.64 stress
 5640 alovela+  15  -5    7308    100      0 R  96.2  0.0   2:30.63 stress
 5643 alovela+  15  -5    7308    100      0 R  96.2  0.0   2:30.71 stress
    1 root      20   0   34024   3328   1496 S   0.0  0.0   0:02.25 init
    2 root      20   0       0      0      0 S   0.0  0.0   0:00.01 kthreadd
```

1.11. Managing the startup process and related services

1.11.1. Boot process

- The Basic Input/Output System (BIOS) is the lowest level interface between the computer and peripherals. On boot it performs integrity checks on memory and seeks instructions on the Master Boor Record (MBR) on the first drive.
- The MBR points to the GRand Unified Bootloader (GRUB).
- GRUB lists the Operating System (OS) labels and the user will select, or the default is selected to identify which kernel to run and which partition, on which drive it is located.
- GRUB then loads the GNU/Linux OS.
- The GNU/Kernel loads the kernel which executes the **init** program. **init** is the root/parent of all processes executing on Linux.
- The first processes that **init** starts is:
    - **SysV** - **/etc/inittab**.
    - **upstart** - **/sbin/init**.
        - As part of the upstart initialisation it runs **/etc/init/rc.conf** to start the legacy SysV init system.
    - **Systemd** - **/lib/systemd/system/default.target** plus the files in **/etc/systemd/system/** and **/lib/systemd/system/**.

Based on the appropriate run-level, scripts are executed to start various processes to run the system and make it functional.

The **init** process is the last step in the boot procedure and identified by process id "1". **init** is responsible for starting system processes.

1.11.2. Runlevels

Runlevels are sets of system configurations. Runlevels for Debian and Ubuntu systems are:

The default runlevel is 2.

Level	Description
0	System halt.
1	Single-User mode.
2	Graphical multi-user plus networking.
3	Same as "2", but not used.
4	Same as "2", but not used.
5	Same as "2", but not used.
6	System reboot.

Display the current runlevel.

```
$ runlevel
N 2
```

To change runlevel immediately, use one of the commands below:

```
$ sudo reboot

$ sudo shutdown -h now                                        # Halt now

$ sudo shutdown +3 "The system will shutdown in 3 minutes"    # Halt in 3 minutes

Broadcast message from alovelace@linuxSys
      (/dev/pts/3) at 9:11 ...

The system is going down for maintenance in 3 minutes!
The system will shutdown in 3 minutes


$ sudo telinit 0      # change the system runlevel to 0 will halt system
```

1.11.3. System and service managers

Process are managed using the GNU/Linux using an initialisation **init** system.

- **SysV init** is the first process started during boot and is assigned PID 1.
  - Init is started by the kernel using a hard-coded filename, and if the kernel is unable to start it, a kernel panic will result.
  - This system is in the process of being replaced in GNU/Linux distributions by **systemd**.
- **Upstart** is an event-based replacement for the **/sbin/init** daemon which handles starting of tasks and services during boot, stopping them during shutdown and supervising them while the system is running.
  - It was developed and used by Ubuntu.
  - When Debian GNU/Linux decided to use systemd as its replacement for **/sbin/init**, Ubuntu announced that it would follow.
- **systemd** is a system and service manager for Linux which:
  - provides aggressive parallelisation capabilities.
  - uses socket and D-Bus activation for starting services.
  - offers on-demand starting of daemons.
  - keeps track of processes using Linux control groups.
  - supports snapshotting and restoring of the system state.
  - maintains mount and automount points.
  - implements an elaborate transactional dependency-based service control logic.

1.11.3.1. SysV

SystemV (SysV) is the traditional UNIX/Linux **init** system. It is essentially a number of process management scripts grouped into runlevels.

- /**etc**/**init.d** contains the actual scripts for each process (service).
- **rc0.d** - The symbolic links in this directory are executed once when entering runlevel 0 (Halt).
- **rc1.d** - The symbolic links in this directory are executed once when entering runlevel 1 (Single-User mode).
- **rc2.d** - The symbolic links in this directory are executed once when entering runlevel 2 (Graphical multi-user plus networking).
- **rc3.d** - The symbolic links in this directory are executed once when entering runlevel 3 (Same as 2 - Not used).
- **rc4.d** - The symbolic links in this directory are executed once when entering runlevel 4 (Same as 2 - Not used).
- **rc5.d** - The symbolic links in this directory are executed once when entering runlevel 5 (Same as 2 - Not used).
- **rc6.d** - The symbolic links in this directory are executed once when entering runlevel 6 (Same as 2 - Not used).
- **rcS.d** - The symbolic links in this directory whose names begin with an 'S' are executed once when booting the system.

The actual scripts are all contained in the /**etc**/**init.d** directory. Each of the other **rcX.d** directories contain Start and Stop symbolic links to the scripts in /**etc**/**init.d**. These scripts are named either **SXX<name>** or **KXX<name>** where:

- **S** - Start
- **K** - Stop
- **XX** - Order number
- **<name>** - name of script in /**etc**/**init.d**

```
$ file /etc/rc1.d/K20hddtemp
/etc/rc1.d/K20hddtemp: symbolic link to `../init.d/hddtemp'
```

If a new script is added to /**etc**/**init.d**, manual symbolic links can be created in the various **rcX.d** directories or a script called **update-rc.d** can be used to make links to start the service in runlevels 2345 and to stop the service in runlevels 016.

```
$ sudo update-rc.d hddtemp defaults
 System start/stop links for /etc/init.d/hddtemp already exist.
```

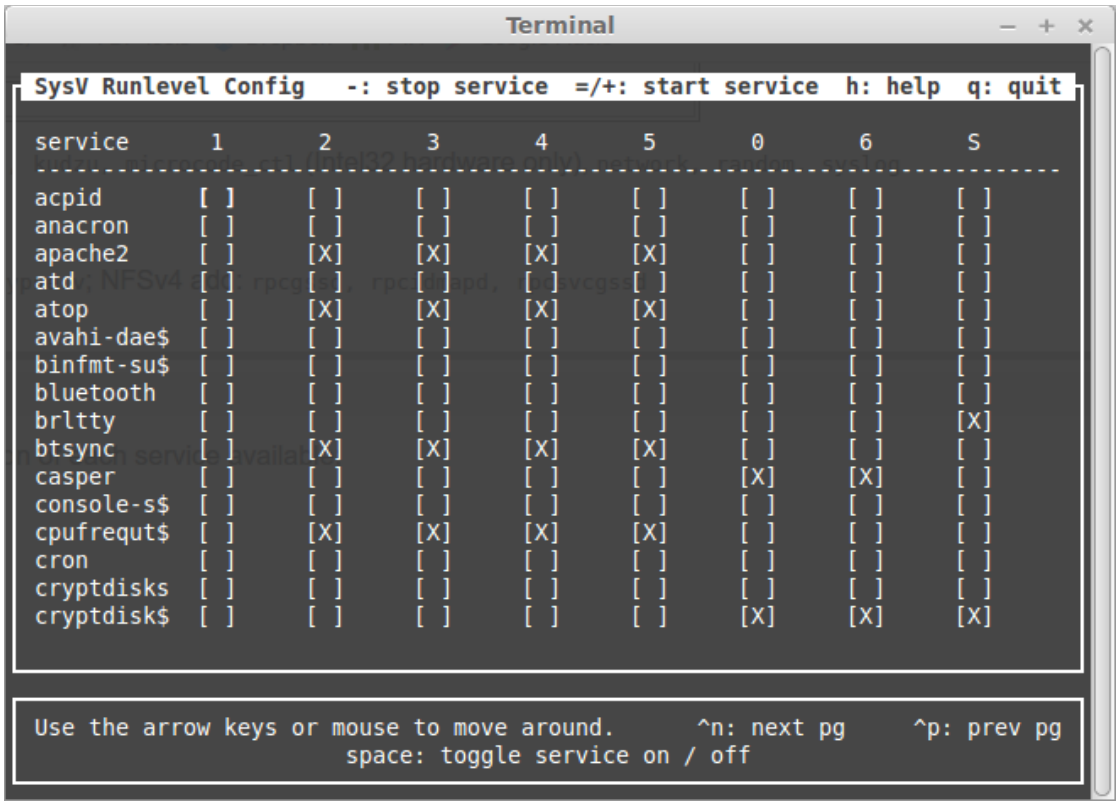
Individual scripts can be ran directly from **/etc/init.d** (or with the service utility described below). Here is an example stopping the Apache2 Server.

```
/etc/init.d $ ./apache2
Usage: apache2 {start|stop|graceful-stop|restart|reload|force-reload|start-
       htcacheclean|stop-htcacheclean}

/etc/init.d $ ./apache2 stop
 * Stopping web server apache2
 *

/etc/init.d $ ./apache2 status
 * apache2 is not running
```

Determine the runlevels for processes

Install **sysv-rc-conf**, a Run-level configuration for SysV like init script links.

```
$ sudo apt-get install sysv-rc-conf
```



service

Use of the **service** utility with command options. Typical options in the scripts are:

- **start**
- **stop**
- **restart**
- **reload**
- **status**
- **list**
- **show**

```
$ service --status-all
 [ + ]  acpid
 [ - ]  anacron
 [ + ]  apache2
 [ + ]  atd
 [ + ]  atop
 [ + ]  avahi-daemon
 [ ? ]  binfmt-support
 [ + ]  bluetooth
 [ - ]  brltty
 [ + ]  btsync
 [ - ]  casper
 [ ? ]  console-setup
 [ ? ]  cpufrequtils
```

Review a specific process.

```
$ service networking status
networking start/running
```

Start a particular process.

```
$ service apache2
Usage: apache2 {start|stop|graceful-stop|restart|reload|force-reload|start-
       htcacheclean|stop-htcacheclean}

/etc/init.d $ service apache2 start
 * Starting web server apache2
 *

$ service apache2 status
 * apache2 is running
```

1.11.3.2. Upstart

initctl command has a number of command options.

- **start**
- **stop**
- **restart**
- **reload**
- **status**
- **list**

```
$ initctl list
avahi-cups-reload stop/waiting
avahi-daemon start/running, process 1127
mountall-net stop/waiting
mountnfs-bootclean.sh start/running
nmbd start/running, process 1954
passwd stop/waiting
rc stop/waiting
rsyslog start/running, process 919
startpar-bridge stop/waiting
tty4 start/running, process 1537
udev start/running, process 569
upstart-udev-bridge start/running, process 556
```

Review a specific process.

```
$ initctl list | grep ^networking
networking start/running

$ initctl status networking
networking start/running
```

1.11.3.3. systemd

Use of the **systemctl** utility with command options. Typical options in the scripts are:

- **start**
- **stop**
- **restart**
- **reload**
- **status**
- **list**
- **show**

```
$ systemctl status networking
networking start/running
```

This page is intentionally blank

2. Command-line

2.1. Editing text files on the command line

2.1.1. VI

vim is the Vi IMproved, a programmers text editor.

Save and Exit

:q[uit]	Quit Vim. This fails when changes have been made.
:wq!	Write the current file and exit always.

Inserting Text

a	Append text after the cursor [count] times.
A	Append text at the end of the line [count] times.
i	Insert text before the cursor [count] times.
I	Insert text before the first non-blank in the line [count] times.
gI	Insert text in column 1 [count] times.
o	Begin a new line below the cursor and insert text, repeat [count] times.
O	Begin a new line above the cursor and insert text, repeat [count] times.
<ESC>	Escape from edit mode.

Deleting text

<Del>	Delete [count] characters under and after the cursor.
x	Delete [count] characters under and after the cursor.
X	Delete [count] characters before the cursor.
d{motion}	Delete text that {motion} moves over.
dd	Delete [count] lines.
D	Delete the characters under the cursor until the end of the line.

Undo|Redo |Repeat

u	Undo [count] changes.
:u[ndo]	Undo one change.
CTRL-R	Redo [count] changes which were undone.
:red[o]	Redo one change which was undone.
U	Undo all latest changes on one line. {Vi: while not moved off of it}.
.	Repeat last change, with count replaced with [count].

Searching

/{pattern}[/]	Search forward for the [count]'th occurrence of {pattern}.
/<CR>	Search forward for the [count]'th latest used pattern.
?<CR>	Search backward for the [count]'th latest used pattern.
n	Repeat the latest "/" or "?" [count] times.
N	Repeat the latest "/" or "?" [count] times in opposite direction.

Moving Around

Basic motion commands:

h	Move left one character (or left arrow).
l	Move Right one character (or right arrow).
k	Move up one line (or up arrow).
j	Move down one line (or down arrow).
0	To the first character of the line.
<Home>	To the first character of the line.
^	To the first non-blank character of the line.
$	To the end of the line.
<End>	To the end of the line.

2.1.2. Vim

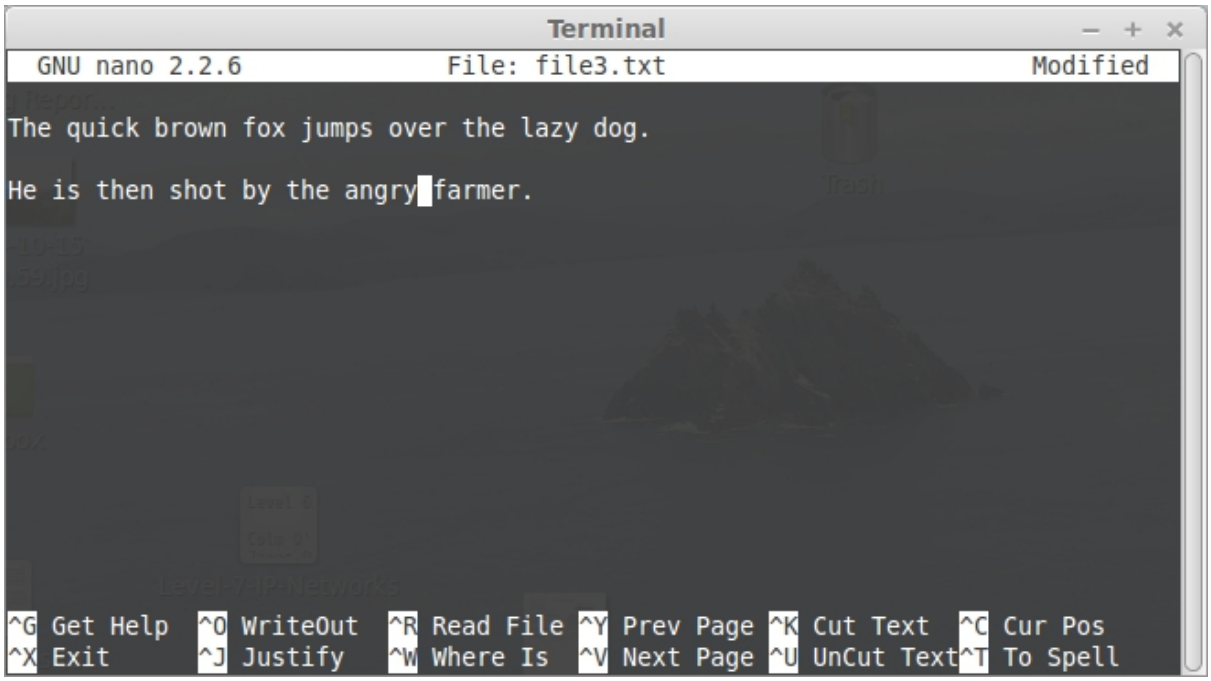
Follow the sequence below to practice creating and editing a file using **vim**.

```
$ vi file3.txt
[Press i] The quick brown fox jumps over the lazy dog. [Press ESC :wq]

$ cat file3.txt
The quick brown fox jumps over the lazy dog.

$ vi file3.txt
The quick brown fox jumps over the lazy dog. [Press o]
[Press CR]
He is then shot by the farmer. [Press ESC :wq]

$ vi file3.txt
The quick brown fox jumps over the lazy dog. [Press j twice (or scroll down to
last line]

He is then shot by the farmer. [Press l or scroll right until curser is on f]
[Press i][type angry ]
[Press ESC :wq]

$ cat file3.txt
The quick brown fox jumps over the lazy dog.

He is then shot by the angry farmer.
```

2.2.2. nano

Alternatively use **GNU nano**. Nano is ANOther editor, an enhanced free Pico clone

```
$ nano file3.txt
```



- Press **Control - X**.
- Press **Y**.
- Confirm filename, Press **CR**.

2.2. Manipulating text files from the command line

Using the following file as the basis for demonstration.

```
$ cat printer.txt
My printer will drive me insane,
I'm always refilling its ink,
it empties my purse,
to make matters worse,
it's usually on the blink!
```

2.2.1. tac

The **tac** command is the inverse of **cat**. It prints files in reverse.

```
$ cat users.txt
lmenabrea
cbabbage
alovelace

$ tac users.txt
alovelace
cbabbage
lmenabrea
```

2.2.2. Stream Editor (sed)

sed is a stream editor for filtering and transforming text.

In this example the first instance of the string **insane** is replaced by the string **to drink**. Note that the original file is not overwritten so to save the output it must be redirected into another file.

```
$ sed 's/insane/to drink/' printer.txt
My printer will drive me to drink,
I'm always refilling its ink,
it empties my purse,
to make matters worse,
it's usually on the blink!

$ cat printer.txt
My printer will drive me insane,
I'm always refilling its ink,
it empties my purse,
to make matters worse,
it's usually on the blink!

$ sed 's/insane/to drink/' printer.txt > printer2.txt

$ cat printer2.txt
My printer will drive me to drink,
I'm always refilling its ink,
it empties my purse,
to make matters worse,
it's usually on the blink!
```

So what is the difference between the following outputs and why ?

```
$ sed 's/a/A/' printer2.txt
My printer will drive me to drink,
I'm Always refilling its paper,
it empties my wAllet,
to mAke matters worse,
it's usuAlly broken!

$ sed 's/a/A/g' printer2.txt
My printer will drive me to drink,
I'm AlwAys refilling its pAper,
it empties my wAllet,
to mAke mAtters worse,
it's usuAlly broken!
```

Well in the first output the first lowercase **a** instance on each line is replaced by an uppercase **A**. In the second example the addition of the **g** or global flag changes every instance of **a** to **A**.

What about special characters ? Lets replace **'** with “.

```
$ sed 's/'/"/g' printer2.txt
>
```

A problem, so each special character must be escaped with a backslash.

```
$ sed -e "s/'/\"/g" printer2.txt
My printer will drive me to drink,
I"m always refilling its paper,
it empties my wallet,
to make matters worse,
it’s usually broken!
```

To print put lines in a file found by a pattern and suppress the other lines use the **-n quiet** option. The **p** flag indicates print the lines found.

```
$ sed -n '/er/p' printer2.txt
My printer will drive me to drink,
I'm always refilling its paper,
to make matters worse,
```

To overwrite (edit) a file sed must be used with the **-i** option which creates a backup of the file being edited first. A file extension is provided, in this case **.bak**.

```
$ cat printer.txt
My printer will drive me insane,
I'm always refilling its ink,
it empties my purse,
to make matters worse,
it's usually on the blink!

$ sed -i.bak 's/printer/scanner/g' printer.txt

$ cat printer.txt
My scanner will drive me insane,
I'm always refilling its ink,
it empties my purse,
to make matters worse,
it's usually on the blink!

$ cat printer.txt.bak
My printer will drive me insane,
I'm always refilling its ink,
it empties my purse,
to make matters worse,
it's usually on the blink!
```

Extract the **Bluetooth** messages from **dmesg**.

```
$ dmesg | sed -n '/Bluetooth/p'
[   35.427264] Bluetooth: Core ver 2.17
[   35.427284] Bluetooth: HCI device and connection manager initialized
[   35.427291] Bluetooth: HCI socket layer initialized
[   35.427293] Bluetooth: L2CAP socket layer initialized
[   35.427297] Bluetooth: SCO socket layer initialized
[   35.474045] Bluetooth: can't load firmware, may not work correctly
[   37.243507] Bluetooth: BNEP (Ethernet Emulation) ver 1.3
[   37.243510] Bluetooth: BNEP filters: protocol multicast
[   37.243517] Bluetooth: BNEP socket layer initialized
[   37.244466] Bluetooth: RFCOMM TTY layer initialized
[   37.244472] Bluetooth: RFCOMM socket layer initialized
[   37.244476] Bluetooth: RFCOMM ver 1.11
```

Extract the comment lines from the /**etc**/**netconfig** file.

```
$ sed -n '/^#/p' /etc/netconfig
#
# The network configuration file. This file is currently only used in
# conjunction with the TI-RPC code in the libtirpc library.
#
# Entries consist of:
#
#       <network_id> <semantics> <flags> <protofamily> <protoname> \
#               <device> <nametoaddr_libs>
#
# The <device> and <nametoaddr_libs> fields are always empty in this
# implementation.
#
```

2.2.3. grep

The **grep** utility is a powerful pattern search tool. There are numerous options so only some common ones are listed here.

Option	Meaning
-c	Count instead of presenting results
-E	Extended regular expression
-H	Print the file name for each match
-h	Suppress the prefixing of file names on output
-i	Ignore case
-l	List only filenames that contain matches
-n	Prefix output with line number
-r	Recursive
-v	Invert match

```
$ grep lmenabrea /etc/passwd
alovelace:x:1002:1003:Ada Lovelace:/home/alovelace:/usr/bin/tcsh

$ sudo grep -n alovelace /etc/passwd
41:alovelace:x:1002:1003:Ada Lovelace:/home/alovelace:/usr/bin/tcsh

$ ls /home
alovelace  cbabbage  lmenabrea

$ ls /home | grep alovelace
alovelace

$ ls /home | grep -v alovelace
lmenabrea
cbabbage
```

Recursively search all files from a point.

```
$ sudo grep -r alovelace /etc/
/etc/gshadow-:alovelace:!::alovelace
/etc/gshadow-:babbage:
$6$Lo92oBZTUm/H$qw5oIp55D.uy3E5xnzZpHKlO3R5sjJwxayizt1vqbFmLzkcnVdD3RJUhC6WbwGyaLsh
Rv6EtofdFDLAbdrp7X/::alovelace
/etc/gshadow:sudo:*::lmenabrea,alovelace
/etc/gshadow:alovelace:!::alovelace
/etc/gshadow:babbage:
$6$Lo92oBZTUm/H$qw5oIp55D.uy3E5xnzZpHKlO3R5sjJwxayizt1vqbFmLzkcnVdD3RJUhC6WbwGyaLsh
Rv6EtofdFDLAbdrp7X/::alovelace
/etc/subuid:alovelace:231072:65536
/etc/passwd:alovelace:x:1002:1003:Ada Lovelace:/home/alovelace:/usr/bin/tcsh
/etc/subgid-:alovelace:231072:65536
/etc/passwd-:alovelace:x:1002:27:Ada Lovelace:/home/alovelace:/usr/bin/tcsh
/etc/shadow:alovelace:
$6$DnyWC4UQ$8bS26d/yiiRdnlj8PTDD8KQpc.bWrDfMCqDcC1FE6XoUDMMDJ6tyn/ZbghwIiUL57kAvcPp
Dd2CoF5bWJl2wA/:0:0:99999:7:::
/etc/subuid-:alovelace:231072:65536
/etc/shadow-:alovelace:
$6$DnyWC4UQ$8bS26d/yiiRdnlj8PTDD8KQpc.bWrDfMCqDcC1FE6XoUDMMDJ6tyn/ZbghwIiUL57kAvcPp
Dd2CoF5bWJl2wA/:16369:0:99999:7:::
/etc/group:sudo:x:27:lmenabrea,alovelace
/etc/group:alovelace:x:1002:alovelace
/etc/group:babbage:x:1003:alovelace
/etc/subgid:alovelace:231072:65536
/etc/group-:alovelace:x:1002:alovelace
/etc/group-:babbage:x:1003:alovelace
```

Recursively search but supress the filename at the beginning of the line.

```
  $ sudo grep -rh alovelace /etc/
  alovelace:!::alovelace
  babbage:
$6$Lo92oBZTUm/H$qw5oIp55D.uy3E5xnzZpHKlO3R5sjJwxayizt1vqbFmLzkcnVdD3RJUhC6WbwGyaLsh
Rv6EtofdFDLAbdrp7X/::alovelace
  sudo:*::lmenabrea,alovelace
  alovelace:!::alovelace
  babbage:
$6$Lo92oBZTUm/H$qw5oIp55D.uy3E5xnzZpHKlO3R5sjJwxayizt1vqbFmLzkcnVdD3RJUhC6WbwGyaLsh
Rv6EtofdFDLAbdrp7X/::alovelace
  alovelace:231072:65536
  alovelace:x:1002:1003:Ada Lovelace:/home/alovelace:/usr/bin/tcsh
  alovelace:231072:65536
  alovelace:x:1002:27:Ada Lovelace:/home/alovelace:/usr/bin/tcsh
  alovelace:
$6$DnyWC4UQ$8bS26d/yiiRdnlj8PTDD8KQpc.bWrDfMCqDcC1FE6XoUDMMDJ6tyn/ZbghwIiUL57kAvcPp
Dd2CoF5bWJl2wA/:0:0:99999:7:::
  alovelace:231072:65536
  alovelace:
$6$DnyWC4UQ$8bS26d/yiiRdnlj8PTDD8KQpc.bWrDfMCqDcC1FE6XoUDMMDJ6tyn/ZbghwIiUL57kAvcPp
Dd2CoF5bWJl2wA/:16369:0:99999:7:::
  sudo:x:27:lmenabrea,alovelace
  alovelace:x:1002:alovelace
  babbage:x:1003:alovelace
  alovelace:231072:65536
  alovelace:x:1002:alovelace
  babbage:x:1003:alovelace
```

Recursively search files and output only the files that contain matches.

```
  $ sudo grep -rl alovelace /etc/
  /etc/gshadow-
  /etc/gshadow
  /etc/subuid
  /etc/passwd
  /etc/subgid-
  /etc/passwd-
  /etc/shadow
  /etc/subuid-
  /etc/shadow-
  /etc/group
  /etc/subgid
  /etc/group-
```

Use a regular expression to extract groups where Ada Lovelace is the first listed member.

```
  $ sudo grep '[0-9]*:alovelace' /etc/group
  alovelace:x:1002:alovelace
  babbage:x:1003:alovelace
```

2.2.4. cut

The **cut** command filters out fields or columns. Typical options are:

Option	Meaning
-d	Define field delimiter (default is tab)
-c list	Cut by column position
-f list	Cut by field number

```
$ id
uid=1000(lmenabrea) gid=1000(lmenabrea) groups=1000(lmenabrea),4(adm),6(disk),
24(cdrom),27(sudo),30(dip),46(plugdev),108(lpadmin),110(sambashare)

$ id | cut -d ' ' -f1,2
uid=1000(lmenabrea) gid=1000(lmenabrea)
```

2.2.5. sort

The **sort** command is used to sort lines of text files. There are a number of options so here are just some of the most used.

Option	Meaning
-b	Ignore leading blanks
-f	Ignore case
-r	Reverse order
-R	Random sort

```
$ ls /home
alovelace
cbabbage
lmenabrea

$ ls /home | sort -r
lmenabrea
cbabbage
alovelace
```

2.2.6. tr

The **tr** translate command translates characters in a file from one form to another.

```
$ cat printer2.txt
My printer will drive me to drink,
I'm always refilling its paper,
it empties my wallet,
to make matters worse,
it’s usually broken!

$ cat printer2.txt | tr [:upper:] [:lower:]
my printer will drive me to drink,
i'm always refilling its paper,
it empties my wallet,
to make matters worse,
it’s usually broken!
```

2.2.7. nl

To write a file to standard output with line numbers added use the **nl** command.

```
$ ls /home | nl > users.txt

$ cat users.txt
     1        lmenabrea
     2        cbabbage
     3        alovelace

$ ls /home | nl | sed 's/^[ \t]* //g' | sed 's/\t/ /g'
1 lmenabrea
2 cbabbage
3 alovelace

$ ls /home | nl | sed 's/^[ \t]* //g' | sed 's/\t/ /g' > users_list.txt

$ cat users_list.txt
1 alovelace
2 cbabbage
3 johnny
```

2.2.8. Join

The **join** command is used to join lines of two files on a common field. In the example the common field is the line number, the output links these as shown.

```
$ cat roles.txt
1 mathematician
2 inventor
3 programmer

$ join users_list.txt roles.txt
1 lmenabrea mathematician
2 cbabbage inventor
3 alovelace programmer
```

2.2.9. uniq

The **uniq** utility can be used to filter matching lines from input to output. The **-c** option prefix lines by the number of occurrences while the **-u** switch option only prints unique lines. **-w** can be used to compare no more than N characters in lines.

```
$ cat numbers.txt
1 2 5 3 3 4 8 9 7 6 5 4 3 2 5 6 7 8 9 1 2 5 3 3 4 8 9 7 6 5 4 3 2 5 6 7 8 9 1 2 5
3 3 4 8 9 7 6 5 4 3 2 5 6 7 8 9 1 2 5 3 3 4 8 9 7 6 5 4 3 2 5 6 7 8 9 1 2 5 3 3 4
8 9 7 6 5 4 3 2 5 6 7 8 9 1

$ cat numbers.txt | sed 's/ /\n/g' | sort | uniq
1
2
3
4
5
6
7
8
9
```

2.2.10. awk

awk is a pattern scanning and processing language. This is a whole language in itself so it is best analise an example.

```
$ df -h
Filesystem                 Size  Used Avail Use% Mounted on
/dev/mapper/mint--vg-root  451G  155G  273G  37% /
none                       4.0K     0  4.0K   0% /sys/fs/cgroup
udev                       3.7G  4.0K  3.7G   1% /dev
tmpfs                      756M  1.7M  755M   1% /run
none                       5.0M     0  5.0M   0% /run/lock
none                       3.7G   27M  3.7G   1% /run/shm
none                       100M   20K  100M   1% /run/user
/dev/sda1                  236M   77M  147M  35% /boot

$ df -h | awk '/none/'
none                       4.0K     0  4.0K   0% /sys/fs/cgroup
none                       5.0M     0  5.0M   0% /run/lock
none                       3.7G   27M  3.7G   1% /run/shm
none                       100M   20K  100M   1% /run/user

$ df -h | awk '/none/ {print $6, "\t", $4}'
/sys/fs/cgroup         4.0K
/run/lock      5.0M
/run/shm       3.7G
/run/user      100M
```

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3. File-system & Storage

3.1. Archiving and compressing files and directories

GNU **tar** is the GNU version of the tar archiving utility. Originally that was the **t**ape **ar**chive. It is useful to **tar up** a directory and all the directories and file therein as a single file, the tar archive file. The GNU tar program can do this. The resultant file is generally called a **tarball**.

```
$ tar -cf sandbox.tar sandbox

$ $ file sandbox.tar
sandbox.tar: POSIX tar archive (GNU)
```

Review a tar archive with the **-t** or **--list** option to see a table of contents for the archive.

```
$ tar -tf sandbox.tar
sandbox/
sandbox/file2.txt
sandbox/file1.txt
sandbox/file3.txt
sandbox/hello.sh
```

Remove the original directory.

```
$ rm -r sandbox
```

Extract the archive and confirm the directory is recovered.

```
$ tar -xf sandbox.tar

$ ls sandbox
file1.txt  file2.txt  file3.txt  hello.sh
```

3.1.0.1. Compression

The tar archive can be compressed to reduce file size. For example **gzip** which reduces the size of files using Lempel-Ziv coding (LZ77) can be applied to the tarball. tar has the ability to incorporate compression functions as well as archiving and perform both functions with the same command.

```
$ tar sandbox.tar

$ ls -l |grep sandbox.tar
-rw-r--r-- 1 lmenabrea lmenabrea     506 Oct 24 13:49 sandbox.tar.gz
```

To reverse this process use the **gunzip** command.

```
$ gunzip sandbox.tar.gz

$ ls -l |grep sandbox.tar
-rw-r--r-- 1 lmenabrea lmenabrea   10240 Oct 24 13:49 sandbox.tar
```

An alternative approach is to use the **bzip2** utility which uses the Burrows-Wheeler block sorting text compression algorithm, and Huffman coding. **bzip2** compression is generally considerably better that the more conventional LZ77/LZ78-based compressors.

```
$ bzip2 sandbox.tar

$ ls -l |grep sandbox.tar
-rw-r--r-- 1 lmenabrea lmenabrea     507 Oct 24 13:49 sandbox.tar.bz2
```

The reverse process is similar to what has been seen for **gunzip**.

```
$ bunzip2 sandbox.tar.bz2

$ ls -l |grep sandbox.tar
-rw-r--r-- 1 lmenabrea lmenabrea   10240 Oct 24 13:49 sandbox.tar
```

Fortunately the **tar** utility offers the ability to both archive and compress in one operation, here is an example using **gzip**. Note the file extension for a gzipped archives is either **.tar.gz** or simply **.tgz**. The **z** switch in the command instructs that the directory be archived and gzipped.

```
$ tar -czf sandbox.tar.gz sandbox

$ ls -l |grep sandbox.tar
-rw-r--r-- 1 lmenabrea lmenabrea     451 Oct 24 13:56 sandbox.tar.gz

$ file sandbox.tar.gz
sandbox.tar.gz: gzip compressed data, from Unix, last modified: Fri Oct 24
13:56:47 2014
```

A similar process can be achieved for **bzip2**, the end extension being **.tar.bz2** or **.tbz2** by convention. The **j** switch is used to archive and **bzip2**.

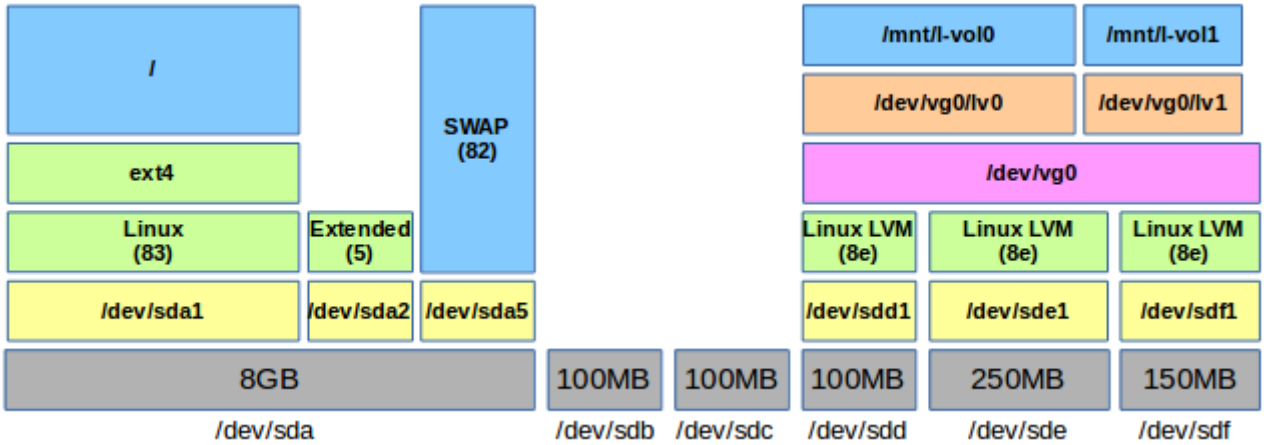
```
$ tar -cjf sandbox.tar.bz2 sandbox

$ ls -l |grep sandbox.tar
-rw-r--r-- 1 lmenabrea lmenabrea     463 Oct 24 13:56 sandbox.tar.bz2

$ file sandbox.tar.bz2
sandbox.tar.bz2: bzip2 compressed data, block size = 900k
```

Comparing the relative sizes of the archive and the two compressed versions. When the requirement is very fast compression, the **gzip** is the best option, it has also very small memory footprint, making it ideal for systems with limited memory. **bzip2** creates about 15% smaller files than **gzip** on average however it compresses at a slower rate than **gzip**. For decompression a similar picture emerges with **gzip** the fastest. **bzip2** is a lot slower taking four to twelve times more time to decompress than **gzip**.

```
$ ls -l |grep sandbox.tar
-rw-r--r-- 1 lmenabrea lmenabrea   10240 Oct 24 13:49 sandbox.tar
-rw-r--r-- 1 lmenabrea lmenabrea     463 Oct 24 13:56 sandbox.tar.bz2
-rw-r--r-- 1 lmenabrea lmenabrea     451 Oct 24 13:56 sandbox.tar.gz
```

3.2. Logical Volume Manager (LVM)

In GNU/Linux RAID is often grouped with Logical Volume Manager (**LVM**) as they share functionality however they are not the same. LVM allows for the clustering of disks, Physical Volumes (**PV**) into Volume Groups (**VG**), these VGs are mapped to Logical Volumes (**LV**) that are interpreted by the OS as partitions.



Referring to the diagram, the physical volumes **sdd**, **sde** and **sdf** are grouped together into a logical volume **vg0**. Two logical volumes **lv0** and **lv1** are created on **vg0** thereby allowing the logical volumes to be numbered and sized without recourse to the size of the individual physical volumes, save the overall size limitation of their sum.

3.2.1. LVM Configuration

Install Logical Volume Manager v2 (lvm2).

```
$ sudo apt-get install lvm2
```

To demonstrate a number of additional drives are connected to the server. To view them use the command **lsblk**.

```
$ lsblk
NAME   MAJ:MIN RM   SIZE RO TYPE MOUNTPOINT
sda      8:0    0     8G  0 disk
├─sda1   8:1    0     7G  0 part /
├─sda2   8:2    0     1K  0 part
└─sda5   8:5    0  1022M  0 part [SWAP]
sdb      8:16   0   100M  0 disk
sdc      8:32   0   100M  0 disk
sdd      8:48   0   100M  0 disk
sde      8:64   0   250M  0 disk
sdf      8:80   0   150M  0 disk
sr0     11:0    1  1024M  0 rom
```

Taking the last three (sdd, sde, sdf) create partitions on each of type Linux LVM (id: 8e) using **fdisk**.

```
$ sudo fdisk /dev/sdd
[sudo] password for lmenabrea: italy

Command (m for help): n
Partition type:
   p   primary (0 primary, 0 extended, 4 free)
   e   extended
Select (default p): p
Partition number (1-4, default 1): 1
First sector (2048-511999, default 2048):
Using default value 2048
Last sector, +sectors or +size{K,M,G} (2048-511999, default 511999):
Using default value 511999

Command (m for help): t
Selected partition 1
Hex code (type L to list codes): 8e
Changed system type of partition 1 to 8e (Linux LVM)

Command (m for help): p

Disk /dev/sdd: 262 MB, 262144000 bytes
64 heads, 32 sectors/track, 250 cylinders, total 512000 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: 0x3111f8f6

   Device Boot      Start         End      Blocks   Id  System
/dev/sdd1            2048      511999      254976   8e  Linux LVM

Command (m for help): w
The partition table has been altered!

Calling ioctl() to re-read partition table.
Syncing disks.
```

Perform the same action on the **sde** and **sdf** drives. When complete review all three.

```
$ sudo fdisk -l /dev/sdd

Disk /dev/sdd: 104 MB, 104857600 bytes
64 heads, 32 sectors/track, 100 cylinders, total 204800 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: 0xb4faec8d

   Device Boot      Start         End      Blocks   Id  System
/dev/sdd1            2048      204799      101376   8e  Linux LVM


$ sudo fdisk -l /dev/sde

Disk /dev/sde: 262 MB, 262144000 bytes
64 heads, 32 sectors/track, 250 cylinders, total 512000 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: 0x3111f8f6

   Device Boot      Start         End      Blocks   Id  System
/dev/sde1            2048      511999      254976   8e  Linux LVM


$ sudo fdisk -l /dev/sdf

Disk /dev/sdf: 157 MB, 157286400 bytes
64 heads, 32 sectors/track, 150 cylinders, total 307200 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: 0x9bd4d0f0

   Device Boot      Start         End      Blocks   Id  System
/dev/sdf1            2048      307199      152576   8e  Linux LVM

$ lsblk
NAME   MAJ:MIN RM   SIZE RO TYPE MOUNTPOINT
sda      8:0    0     8G  0 disk
├─sda1   8:1    0     7G  0 part /
├─sda2   8:2    0     1K  0 part
└─sda5   8:5    0  1022M  0 part [SWAP]
sdb      8:16   0   100M  0 disk
sdc      8:32   0   100M  0 disk
sdd      8:48   0   100M  0 disk
└─sdd1   8:49   0    99M  0 part
sde      8:64   0   250M  0 disk
└─sde1   8:65   0   249M  0 part
sdf      8:80   0   150M  0 disk
└─sdf1   8:81   0   149M  0 part
sr0     11:0    1  1024M  0 rom
```

Initialise these disks for use by LVM with the **pvcreate** command.

```
$ sudo pvcreate /dev/sdd1
  Physical volume "/dev/sdd1" successfully created

$ sudo pvcreate /dev/sde1
  Physical volume "/dev/sde1" successfully created

$ sudo pvcreate /dev/sdf1
  Physical volume "/dev/sdf1" successfully created
```

Create as volume group into which the physical volumes are incorporated.

```
$ sudo vgcreate vg0 /dev/sdd1 /dev/sde1 /dev/sdf1
  Volume group "vg0" successfully created
```

Now create logical volumes as necessary up to the limits on size imposed by the overall volume group size. In this way the logical volumes loose the limitations of the physical volumes. Note the middle command where I attempted to create a logical volume beyond the available space remaining in the volume group.

```
$ sudo lvcreate --size 300M --name lv0 vg0
  Logical volume "lv0" created

$ sudo lvcreate --size 200M --name lv1 vg0
  Volume group "vg0" has insufficient free space (48 extents): 50 required.

$ sudo lvcreate --size 175M --name lv1 vg0
  Rounding up size to full physical extent 176.00 MiB
  Logical volume "lv1" created
```

Display the physical and logical volumes.

```
$ sudo pvdisplay
  --- Physical volume ---
  PV Name               /dev/sdd1
  VG Name               vg0
  PV Size               99.00 MiB / not usable 3.00 MiB
  Allocatable           yes
  PE Size               4.00 MiB
  Total PE              24
  Free PE               4
  Allocated PE          20
  PV UUID               rl7d2z-dmUs-8p8I-hrSW-zViM-Di3x-7Bw0gb

  --- Physical volume ---
  PV Name               /dev/sde1
  VG Name               vg0
  PV Size               249.00 MiB / not usable 0
  Allocatable           yes (but full)
  PE Size               4.00 MiB
  Total PE              62
  Free PE               0
  Allocated PE          62
  PV UUID               O3veTC-6QUv-q0A6-6wzx-ag2Q-Gm8e-seQIYm
```

```
  --- Physical volume ---
  PV Name               /dev/sdf1
  VG Name               vg0
  PV Size               149.00 MiB / not usable 0
  Allocatable           yes (but full)
  PE Size               4.00 MiB
  Total PE              37
  Free PE               0
  Allocated PE          37
  PV UUID               1kLr3o-o6Ff-U0uq-6404-qgKR-PtzV-0xale8


$ sudo vgdisplay
  --- Volume group ---
  VG Name               vg0
  System ID
  Format                lvm2
  Metadata Areas        3
  Metadata Sequence No  3
  VG Access             read/write
  VG Status             resizable
  MAX LV                0
  Cur LV                2
  Open LV               0
  Max PV                0
  Cur PV                3
  Act PV                3
  VG Size               492.00 MiB
  PE Size               4.00 MiB
  Total PE              123
  Alloc PE / Size       119 / 476.00 MiB
  Free  PE / Size       4 / 16.00 MiB
  VG UUID               DFYG3z-dTyu-9sQq-RMys-T8Rn-n2Vm-kacVte


$ sudo lvdisplay
  --- Logical volume ---
  LV Path                /dev/vg0/lv0
  LV Name                lv0
  VG Name                vg0
  LV UUID                2cyBm2-0u7C-wBR8-DMjZ-p4lb-gJLW-CmLubL
  LV Write Access        read/write
  LV Creation host, time ubuntu-vm, 2014-12-03 06:57:49 +0000
  LV Status              available
  # open                 0
  LV Size                300.00 MiB
  Current LE             75
  Segments               2
  Allocation             inherit
  Read ahead sectors     auto
  - currently set to     256
  Block device           252:0

  --- Logical volume ---
  LV Path                /dev/vg0/lv1
  LV Name                lv1
  VG Name                vg0
  LV UUID                ixcdGg-LDMy-Rtnc-kIU6-03R4-L1Hl-7giTDI
  LV Write Access        read/write
  LV Creation host, time ubuntu-vm, 2014-12-03 06:58:26 +0000
  LV Status              available
  # open                 0
  LV Size                176.00 MiB
  Current LE             44
  Segments               2
  Allocation             inherit
  Read ahead sectors     auto
  - currently set to     256
  Block device           252:1
```

These logical volumes can be addressed as either:

- /dev/vg0/lv0
- /dev/vg0/lv1

or

- /dev/mapper/vg0-lv0
- /dev/mapper/vg0-lv1

Make a filesystem on the logical volumes, create mount points and mount.

```
$ sudo ls /dev/mapper
control  vg0-lv0  vg0-lv1

$ sudo mkfs.ext4 /dev/vg0/lv0
mke2fs 1.42.9 (4-Feb-2014)
Filesystem label=
OS type: Linux
Block size=1024 (log=0)
Fragment size=1024 (log=0)
Stride=0 blocks, Stripe width=0 blocks
76912 inodes, 307200 blocks
15360 blocks (5.00%) reserved for the super user
First data block=1
Maximum filesystem blocks=67633152
38 block groups
8192 blocks per group, 8192 fragments per group
2024 inodes per group
Superblock backups stored on blocks:
      8193, 24577, 40961, 57345, 73729, 204801, 221185

Allocating group tables: done
Writing inode tables: done
Creating journal (8192 blocks): done
Writing superblocks and filesystem accounting information: done

$ sudo mkfs.ext4 /dev/vg0/lv1
mke2fs 1.42.9 (4-Feb-2014)
Filesystem label=
OS type: Linux
Block size=1024 (log=0)
Fragment size=1024 (log=0)
Stride=0 blocks, Stripe width=0 blocks
45056 inodes, 180224 blocks
9011 blocks (5.00%) reserved for the super user
First data block=1
Maximum filesystem blocks=67371008
22 block groups
8192 blocks per group, 8192 fragments per group
2048 inodes per group
Superblock backups stored on blocks:
      8193, 24577, 40961, 57345, 73729

Allocating group tables: done
Writing inode tables: done
Creating journal (4096 blocks): done
Writing superblocks and filesystem accounting information: done

$ sudo mkdir /mnt/l-vol0
$ sudo mkdir /mnt/l-vol1

$ sudo mount -t ext4 /dev/vg0/lv0 /mnt/l-vol0
$ sudo mount -t ext4 /dev/vg0/lv1 /mnt/l-vol1
```

```
$ df -h
Filesystem           Size  Used Avail Use% Mounted on
/dev/sda1            6.8G  1.7G  4.8G  27% /
none                 4.0K     0  4.0K   0% /sys/fs/cgroup
udev                 487M  4.0K  487M   1% /dev
tmpfs                100M  460K   99M   1% /run
none                 5.0M     0  5.0M   0% /run/lock
none                 498M     0  498M   0% /run/shm
none                 100M     0  100M   0% /run/user
/dev/mapper/vg0-lv0  283M  2.1M  262M   1% /mnt/l-vol0
/dev/mapper/vg0-lv1  167M  1.6M  153M   1% /mnt/l-vol1

$ mount | grep lv
/dev/mapper/vg0-lv0 on /mnt/l-vol0 type ext4 (rw)
/dev/mapper/vg0-lv1 on /mnt/l-vol1 type ext4 (rw)
```

Unmount the temporary mounts.

```
$ sudo umount /dev/vg0/lv0
$ sudo umount /dev/vg0/lv1
```

For persistence add to the /**etc**/**fstab** file.

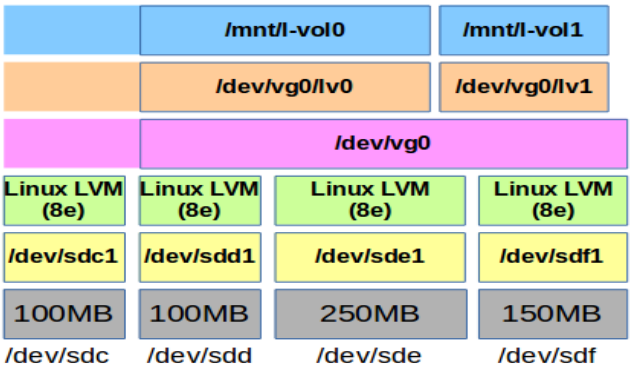
```
$ sudo -s
# echo -e "\n#Entries for LVM Logical volumes" >> /etc/fstab
# echo "/dev/vg0/lv0   /mnt/l-vol0   ext4   defaults   0    0" >> /etc/fstab
# echo "/dev/vg0/lv1   /mnt/l-vol1   ext4   defaults   0    0" >> /etc/fstab
# exit

$ sudo tail -3 /etc/fstab
#Entries for LVM Logical volumes
/dev/vg0/lv0   /mnt/l-vol0     ext4     defaults      0    0
/dev/vg0/lv1   /mnt/l-vol1     ext4     defaults      0    0
```

Mount the logical volumes and confirm.

```
$ sudo mount /dev/vg0/lv0
$ sudo mount /dev/vg0/lv1

$ mount | grep lv
/dev/mapper/vg0-lv0 on /mnt/l-vol0 type ext4 (rw)
/dev/mapper/vg0-lv1 on /mnt/l-vol1 type ext4 (rw)

$ df -h | grep lv
/dev/mapper/vg0-lv0  283M  2.1M  262M   1% /mnt/l-vol0
/dev/mapper/vg0-lv1  167M  1.6M  153M   1% /mnt/l-vol1
```

3.2.2. Adjusting the size of a logical volume

What if I wanted to increase the size of a logical volume, say **lv0**.



Create a partition of type **Linux LVM (8e)** on the drive /**dev**/**sdc**.

```
$ sudo fdisk /dev/sdc

Command (m for help): n
Partition type:
   p   primary (0 primary, 0 extended, 4 free)
   e   extended
Select (default p): p
Partition number (1-4, default 1): 1
First sector (2048-204799, default 2048):
Using default value 2048
Last sector, +sectors or +size{K,M,G} (2048-204799, default 204799):
Using default value 204799

Command (m for help): t
Selected partition 1
Hex code (type L to list codes): 8e
Changed system type of partition 1 to 8e (Linux LVM)

Command (m for help): p

Disk /dev/sdc: 104 MB, 104857600 bytes
64 heads, 32 sectors/track, 100 cylinders, total 204800 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: 0x08cafc4c

   Device Boot      Start         End      Blocks   Id  System
/dev/sdc1            2048      204799      101376   8e  Linux LVM

Command (m for help): w
The partition table has been altered!

Calling ioctl() to re-read partition table.
Syncing disks.
```

3.2.3. Extend the volume group

Extend the volume group by adding the new physical volume, notice the volume groups increased size.

```
$ sudo vgextend vg0 /dev/sdc1
  No physical volume label read from /dev/sdc1
  Physical volume "/dev/sdc1" successfully created
  Volume group "vg0" successfully extended

$ sudo vgdisplay
  --- Volume group ---
  VG Name               vg0
  System ID
  Format                lvm2
  Metadata Areas        4
  Metadata Sequence No  4
  VG Access             read/write
  VG Status             resizable
  MAX LV                0
  Cur LV                2
  Open LV               0
  Max PV                0
  Cur PV                4
  Act PV                4
  VG Size               588.00 MiB
  PE Size               4.00 MiB
  Total PE              147
  Alloc PE / Size       119 / 476.00 MiB
  Free  PE / Size       28 / 112.00 MiB
  VG UUID               GFt0V6-VakN-cASe-FE5Z-0fZp-jKw0-ruhgT2
```

3.2.4. Extend the logical volume

Display the logical volume to be extended.

```
$ sudo lvdisplay /dev/vg0/lv0
  --- Logical volume ---
  LV Path                /dev/vg0/lv0
  LV Name                lv0
  VG Name                vg0
  LV UUID                oAfAgg-Rhua-A457-2TCT-d1tY-J2un-CmlKt5
  LV Write Access        read/write
  LV Creation host, time ubuntu-vm, 2014-12-08 06:14:25 +0000
  LV Status              available
  # open                 0
  LV Size                300.00 MiB
  Current LE             75
  Segments               2
  Allocation             inherit
  Read ahead sectors     auto
  - currently set to     256
  Block device           252:0
```

Now extend the logical volume by 100 MB.

```
$ sudo lvextend --size +100M /dev/vg0/lv0
  Extending logical volume lv0 to 400.00 MiB
  Logical volume lv0 successfully resized

$ sudo lvdisplay /dev/vg0/lv0
  --- Logical volume ---
  LV Path                /dev/vg0/lv0
  LV Name                lv0
  VG Name                vg0
  LV UUID                oAfAgg-Rhua-A457-2TCT-d1tY-J2un-CmlKt5
  LV Write Access        read/write
  LV Creation host, time ubuntu-vm, 2014-12-08 06:14:25 +0000
  LV Status              available
  # open                 0
  LV Size                400.00 MiB
  Current LE             100
  Segments               4
  Allocation             inherit
  Read ahead sectors     auto
  - currently set to     256
  Block device           252:0
```

Alternative approach would be to use the command below. This defines the actual size the new logical volume should be.

```
$ sudo lvextend --size 400M /dev/vg0/lv0
  Extending logical volume lv0 to 400.00 MiB
  Logical volume lv0 successfully resized
```

3.2.4.1. Reduce a logical volume

In a similar mechanism a logical volume can be reduced. Here **lv0** is reduced to 100MB.

```
$ sudo lvreduce --size 100M /dev/vg0/lv0
  WARNING: Reducing active logical volume to 100.00 MiB
  THIS MAY DESTROY YOUR DATA (filesystem etc.)
  Do you really want to reduce lv0? [y/n]: y
  Reducing logical volume lv0 to 100.00 MiB
  Logical volume lv0 successfully resized
```

3.2.4.2. Create a filesystem on logical volume

Create a filesystem on the **lv0**, mount and add a file.

```
$ sudo mkfs.ext4 /dev/vg0/lv0
mke2fs 1.42.9 (4-Feb-2014)
Filesystem label=
OS type: Linux
Block size=1024 (log=0)
Fragment size=1024 (log=0)
Stride=0 blocks, Stripe width=0 blocks
25688 inodes, 102400 blocks
5120 blocks (5.00%) reserved for the super user
First data block=1
Maximum filesystem blocks=67371008
13 block groups
8192 blocks per group, 8192 fragments per group
1976 inodes per group
Superblock backups stored on blocks:
      8193, 24577, 40961, 57345, 73729

Allocating group tables: done
Writing inode tables: done
Creating journal (4096 blocks): done
Writing superblocks and filesystem accounting information: done

$ sudo mount /dev/vg0/lv0 /mnt/l-vol0

$ sudo -s
# echo "My file" > /mnt/l-vol0/my_file
# sudo cat /mnt/l-vol0/my_file
My file
```

3.2.5. Create a Snapshot of the Logical volumes

When resizing volumes it is useful to create a snapshot of logical volumes with the lvcreate **-s** or **--snapshot** switch to ensure that data is not lost.To do so there must be enough room on the volume group first. The following is a demonstration of a snapshot for **lv0**.

```
$ sudo lvcreate --size 100M --snapshot --name l-vol0-snapshot /dev/vg0/lv0
  Logical volume "l-vol0-snapshot" created

$ sudo mkdir /mnt/l-vol0-snapshot/
$ sudo mount /dev/vg0/l-vol0-snapshot /mnt/l-vol0-snapshot/
```

Confirm the new snapshot by checking for the **my_file** on the mount.

```
$ sudo cat /mnt/l-vol0-snapshot/my_file
My file
```

Backup the snapshot.

```
$ sudo tar -cf /backups/l-vol0-snapshot.tar /mnt/l-vol0-snapshot/
$ sudo file /backups/l-vol0-snapshot.tar
/tmp/l-vol0-snapshot.tar: POSIX tar archive (GNU)
```

3.2.6. Removing Logical volumes

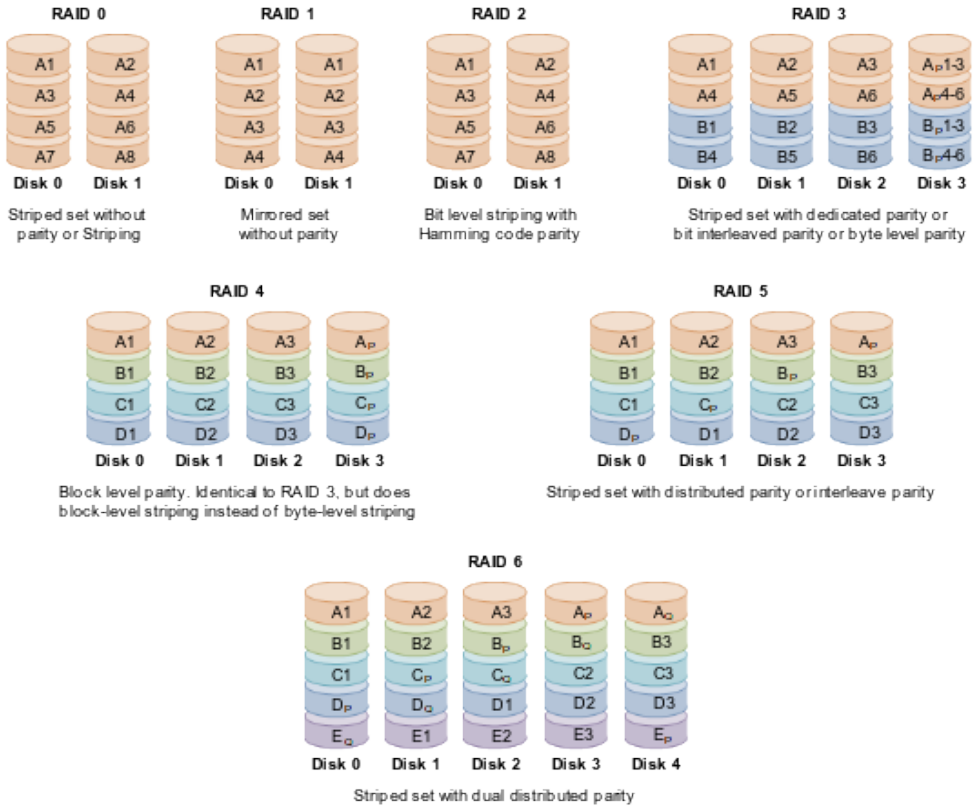
Remove volumes in the reverse order. First remove the lines from /**etc**/**fstab** and then umount before removing the LVM devices.

```
$ sudo umount /dev/vg0/lv0
$ sudo umount /dev/vg0/lv1

$ sudo lvremove /dev/vg0/lv0
Do you really want to remove and DISCARD active logical volume lv0? [y/n]: y
  Logical volume "lv0" successfully removed

$ sudo lvremove /dev/vg0/lv1
Do you really want to remove and DISCARD active logical volume lv1? [y/n]: y
  Logical volume "lv1" successfully removed

$ sudo vgremove /dev/vg0
  Volume group "vg0" successfully removed

$ sudo pvremove /dev/sdd1
  Labels on physical volume "/dev/sdd1" successfully wiped

$ sudo pvremove /dev/sde1
  Labels on physical volume "/dev/sde1" successfully wiped

$ sudo pvremove /dev/sdf1
  Labels on physical volume "/dev/sdf1" successfully wiped
```

3.3. Assembling partitions as Redundant Array of Independent Disks (RAID) devices

With **RAID** technology it is possible to achieve high levels of storage reliability from low cost and less reliable harddisk components. This is possible by arranging the devices into arrays for redundancy. RAID describes a number of methods to divide and replicate data among multiple harddisk drives. Each RAID Type offers different levels of data reliability and/or Input/Output (**I**/**O**) performance. Physical disks grouped in such configurations are termed RAID arrays. The RAID array distributes data across multiple disks, but from the OS perspective the array is seen as one single disk.

3.3.1. RAID Types

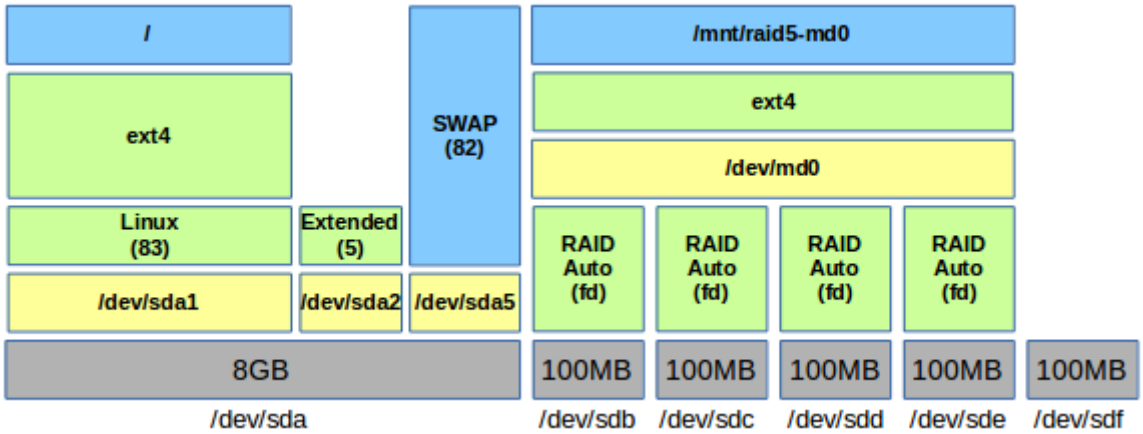


Here is a description of the basic concepts on some RAID types:

RAID Type	Description
0	The data is distributed equally between one or more disks without information on parity or redundancy, without offering fault tolerance. Data is distributed across the disks to increase storage volume, if the disk fails physically, the information will be lost and will have to be recovered from backup copies. What does increase is the performance, depending on the RAID 0 implementation, given that the read and write options will be divided among the different disks. This is often confused with LVM.
1	This RAID type creates an exact copy, a mirror on a set of two or more disks in an array. RAID 1 is useful for the reading performance which can increase lineally with the number of disks. It also adds fault tolerance where a fault occurs to one of the disks as the same information is available on each. RAID 1 is usually adequate for High Availability (**HA**) where resources are needed critically. This configuration also makes it possible to hot swap disks. If a fault is detected in any of the disks, it can be replaced without switching off the system.
2	Unlike earlier RAID types with RAID 2 the data is divided into bits and redundant codes are used for error correction. It is not widely used as a large number of disks is required, one per system bit plus redundancy bits, so for a 32 bit system 39 disks are required.
3	RAID3 uses byte divisions with an additional disk dedicated to the parity of blocks. This is not very widely used type. Depending on the size of the data and the positions, it does not provide simultaneous accesses.
4	RAID 4 is similar to RAID 3, however it stripes the data at the block level, instead of byte level, which means that it is possible to service simultaneous requests when only a single block is requested.
5	Block level striping is used, distributing the parity among the disks. It is widely used, due to the simple parity scheme and due to the fact that this calculation is implemented simply by the hardware, with good performance levels.
6	Block level striping like in RAID 5 with the addition of another parity block, i.e. Block level striping with two parity blocks.
01	A mirror stripe is a nested RAID level where groups of RAID 0 arrays are used in a RAID 1 array to create a mirror between them. An advantage is that, in the event of an error, the RAID 0 level used may be rebuilt thanks to the other copy, but if more disks need to be added, they have to be added to all the RAID 0 groups equally.
10	Striping of mirrors where groups of RAID 1 arrays are used in a RAID 0 array. In each RAID 1 group if a disk fails there is no loss of data. RAID 10 arrays are used with high performance databases as they include both fault tolerance and the speed.

3.3.2. Building RAID Arrays

Looking at an example to build a RAID array across two USB Sticks. Create and format a RAID-1 partition using these two units. Configure the system to automatically mount it into a given location and so that users without administrative rights are allowed to Read and Write files in the partition.



The steps:

- Create partitions on each disk (type fd).
- Creade RAID device with the mdadm.
- Format RAID device.
- Mount RAID device (add to /etc/fstab).
- Capture RAID details to ensure persistence.
- **mdadm -s** can be used to stop RAID.

3.3.2.1. Install the mdadm utility

The GNU/Linux **mdadm** utility provides GNU/Linux Software RAID. Each RAID device is a virtual device created from two or more real block devices. This allows multiple devices to be combined into a single device upon which a single file-system is installed. This example will demonstrate **RAID 1** across two USB Sticks. The USB Sticks will have a file-system created across the RAID array **md0**.

```
$ sudo apt-get install mdadm
```

3.3.2.2. Prepare the disks

In the example we have four 100 MB drives, /**dev**/**sdb,** /**dev**/**sdc,** /**dev**/**sdd,** /**dev**/**sde**.

Use the **lsblk** command to see the physical layout.

```
$ lsblk
NAME   MAJ:MIN RM   SIZE RO TYPE MOUNTPOINT
sda      8:0    0     8G  0 disk
├─sda1   8:1    0     7G  0 part /
├─sda2   8:2    0     1K  0 part
└─sda5   8:5    0  1022M  0 part [SWAP]
sdb      8:16   0   100M  0 disk
sdc      8:32   0   100M  0 disk
sdd      8:48   0   100M  0 disk
sde      8:64   0   100M  0 disk
sdf      8:80   0   100M  0 disk
sr0     11:0    1  1024M  0 rom
```

Delete existing partitions on the USB Sticks. Here is an example for /**dev**/**sdb**, repeat for each of the disks.

```
$ sudo fdisk /dev/sdb

Command (m for help): d
Selected partition 1

Command (m for help): p

Disk /dev/sdc: 8004 MB, 8004304896 bytes
35 heads, 21 sectors/track, 21269 cylinders, total 15633408 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: 0x00000000

   Device Boot      Start         End      Blocks   Id  System

Command (m for help): w
The partition table has been altered!

Calling ioctl() to re-read partition table.

WARNING: Re-reading the partition table failed with error 16: Device or resource
busy.
The kernel still uses the old table. The new table will be used at
the next reboot or after you run partprobe(8) or kpartx(8)
Syncing disks.
```

3.3.2.3. Create RAID Array

Create a RAID 5 Array /**dev**/**md0** comprising block-level striping with distributed parity from the four drives /**dev**/**sdb**, /**dev**/**sdc**, /**dev**/**sdd** and /**dev**/**sde**.

```
$ sudo mdadm --create /dev/md0 --level=5 --raid-devices=4 /dev/sdb /dev/sdc
/dev/sdd /dev/sde

mdadm: Defaulting to version 1.2 metadata
mdadm: array /dev/md0 started.
```

Confirm array is started.

```
$ cat /proc/mdstat
Personalities : [linear] [multipath] [raid0] [raid1] [raid6] [raid5] [raid4] [raid10]
md0 : active raid5 sde[4] sdd[2] sdc[1] sdb[0]
      305664 blocks super 1.2 level 5, 512k chunk, algorithm 2 [4/4] [UUUU]


$ sudo mdadm --detail /dev/md0
[sudo] password for alovelace:
/dev/md0:
        Version : 1.2
  Creation Time : Fri Dec 12 18:46:33 2014
     Raid Level : raid5
     Array Size : 305664 (298.55 MiB 313.00 MB)
  Used Dev Size : 101888 (99.52 MiB 104.33 MB)
   Raid Devices : 4
  Total Devices : 4
    Persistence : Superblock is persistent

    Update Time : Fri Dec 12 18:46:44 2014
          State : clean
 Active Devices : 4
Working Devices : 4
 Failed Devices : 0
  Spare Devices : 0

         Layout : left-symmetric
     Chunk Size : 512K

           Name : ubuntu-vm:0  (local to host ubuntu-vm)
           UUID : 31c0ae28:3cc27473:5dc6bc0c:17f01003
         Events : 18

    Number   Major   Minor   RaidDevice State
       0       8       16        0      active sync   /dev/sdb
       1       8       32        1      active sync   /dev/sdc
       2       8       48        2      active sync   /dev/sdd
       4       8       64        3      active sync   /dev/sde
```

3.3.2.4. Create file-system on RAID Array

Make a file-system on the new RAID Array. In this case an GNU/Linux fourth EXTended file-system (**ext4**).

```
$ sudo mkfs --type ext4 /dev/md0
mke2fs 1.42.9 (4-Feb-2014)
Filesystem label=
OS type: Linux
Block size=1024 (log=0)
Fragment size=1024 (log=0)
Stride=512 blocks, Stripe width=1536 blocks
76608 inodes, 305664 blocks
15283 blocks (5.00%) reserved for the super user
First data block=1
Maximum filesystem blocks=67633152
38 block groups
8192 blocks per group, 8192 fragments per group
2016 inodes per group
Superblock backups stored on blocks:
      8193, 24577, 40961, 57345, 73729, 204801, 221185

Allocating group tables: done
Writing inode tables: done
Creating journal (8192 blocks): done
Writing superblocks and filesystem accounting information: done
```

3.3.2.5. Mount new file-system on Operating System

Mount the new file-system on the OS.

```
$ sudo mkdir /mnt/raid5-md0
$ sudo chown root:disk /mnt/raid5-md0/
$ sudo chmod 775 /mnt/raid5-md0/
```

Add users that require access to the drive to the **disk** group.

```
$ sudo vi /etc/group

...
disk:x:100:lmenabrea,alovelace
...
```

Make persistent, such that after a reboot the RAID array will reform. The **initramfs** needs to be updated so it contains the /**etc**/**mdadm**/**mdadm.conf** settings during boot.

```
$ sudo -s

# echo -e "\n# RAID5" >> /etc/mdadm/mdadm.conf

# mdadm --detail --scan >> /etc/mdadm/mdadm.conf

# echo -e "\n# Mount for RAID 5\n/dev/md0\t/mnt/raid5-md0\text4\tdefaults\t0\t0"
>> /etc/fstab

# mount -a

# update-initramfs -u
update-initramfs: Generating /boot/initrd.img-3.13.0-40-generic

# exit
$
```

Review the new file-system.

```
$ sudo df -h /mnt/raid5-md0/

Filesystem      Size  Used Avail Use% Mounted on
/dev/md0        282M  2.1M  261M   1% /mnt/raid5-md0
```

Change the ownership and permissions of the new mount such that the group is **disk** and the permissions are **775**.

```
$ sudo chown root:disk /mnt/raid5-md0/
$ sudo chmod 775 /mnt/raid5-md0/
```

3.3.2.6. Test file access and persistence

Test that members of the **disk** group can create files on the RAID array partition.

```
$ echo "This is a test" > /mnt/raid5-md0/testfile
$ cat /mnt/raid5-md0/testfile
This is a test
```

After a reboot check the RAID device exists.

```
$ sudo mdadm --detail --scan
ARRAY /dev/md0 metadata=1.2 name=ubuntu-vm:0 UUID=31c0ae28:3cc27473:5dc6bc0c:17f01003

$ sudo mdadm --detail /dev/md0

/dev/md0:
        Version : 1.2
  Creation Time : Fri Dec 12 18:46:33 2014
     Raid Level : raid5
     Array Size : 305664 (298.55 MiB 313.00 MB)
  Used Dev Size : 101888 (99.52 MiB 104.33 MB)
   Raid Devices : 4
  Total Devices : 4
    Persistence : Superblock is persistent

    Update Time : Fri Dec 12 19:14:00 2014
          State : clean
 Active Devices : 4
Working Devices : 4
 Failed Devices : 0
  Spare Devices : 0

         Layout : left-symmetric
     Chunk Size : 512K

           Name : ubuntu-vm:0  (local to host ubuntu-vm)
           UUID : 31c0ae28:3cc27473:5dc6bc0c:17f01003
         Events : 18

    Number   Major   Minor   RaidDevice State
       0       8       16        0      active sync   /dev/sdb
       1       8       32        1      active sync   /dev/sdc
       2       8       48        2      active sync   /dev/sdd
       4       8       64        3      active sync   /dev/sde
```

3.3.2.7. Simulate disk failure

Simulate a fail of the /**dev**/**sdc** disk.

```
$ sudo mdadm /dev/md0 --fail /dev/sdc
```

Upon reboot review the RAID. Notice that /**dev**/**sdc** is marked as **removed**.

```
$ sudo mdadm --detail --scan /dev/md0
/dev/md0:
        Version : 1.2
  Creation Time : Fri Dec 12 18:46:33 2014
     Raid Level : raid5
     Array Size : 305664 (298.55 MiB 313.00 MB)
  Used Dev Size : 101888 (99.52 MiB 104.33 MB)
   Raid Devices : 4
  Total Devices : 4
    Persistence : Superblock is persistent

    Update Time : Fri Dec 12 19:32:45 2014
          State : clean, degraded
 Active Devices : 3
Working Devices : 3
 Failed Devices : 1
  Spare Devices : 0

         Layout : left-symmetric
     Chunk Size : 512K

           Name : ubuntu-vm:0  (local to host ubuntu-vm)
           UUID : 31c0ae28:3cc27473:5dc6bc0c:17f01003
         Events : 20

    Number   Major   Minor   RaidDevice State
       0       8       16        0      active sync   /dev/sdb
       1       0        0        1      removed
       2       8       48        2      active sync   /dev/sdd
       4       8       64        3      active sync   /dev/sde

       1       8       32        -      faulty spare   /dev/sdc
```

Confirm data is intact on single disk

Existing data on the drive is intact.

```
$ sudo df -h /mnt/raid5-md0/
Filesystem      Size  Used Avail Use% Mounted on
/dev/md0        282M  2.1M  261M   1% /mnt/raid5-md0

$ cat /mnt/raid5-md0/testfile
This is a test
```

Check failed disk. Note that **[2/1] [U_]** replaces **[2/2] [UU]** from the earlier runs of the command.

```
$ cat /proc/mdstat
Personalities : [linear] [multipath] [raid0] [raid1] [raid6] [raid5] [raid4] [raid10]
md0 : active raid5 sde[4] sdb[0] sdd[2]
      305664 blocks super 1.2 level 5, 512k chunk, algorithm 2 [4/3] [U_UU]
```

Replace the failed drive with the unused /**dev**/**sdf** drive.

```
$ lsblk
NAME   MAJ:MIN RM   SIZE RO TYPE  MOUNTPOINT
sda      8:0    0     8G  0 disk
├─sda1   8:1    0     7G  0 part  /
├─sda2   8:2    0     1K  0 part
└─sda5   8:5    0  1022M  0 part  [SWAP]
sdb      8:16   0   100M  0 disk
└─md0    9:0    0 298.5M  0 raid5 /mnt/raid5-md0
sdc      8:32   0   100M  0 disk
sdd      8:48   0   100M  0 disk
└─md0    9:0    0 298.5M  0 raid5 /mnt/raid5-md0
sde      8:64   0   100M  0 disk
└─md0    9:0    0 298.5M  0 raid5 /mnt/raid5-md0
sdf      8:80   0   100M  0 disk
sr0     11:0    1  1024M  0 rom
```

Add new disk to RAID array

Now add the new physical /**dev**/**sdf** disk to the RAID array. The new drive will be synchronised

```
$ sudo mdadm --manage /dev/md0 --add /dev/sdf
mdadm: added /dev/sdf
```

Review the RAID status.

```
$ cat /proc/mdstat
Personalities : [linear] [multipath] [raid0] [raid1] [raid6] [raid5] [raid4] [raid10]
md0 : active raid5 sdf[5] sde[4] sdb[0] sdd[2]
      305664 blocks super 1.2 level 5, 512k chunk, algorithm 2 [4/4] [UUUU]

unused devices: <none>
```

Confirm the RAID Array is back to normal.

```
$ sudo mdadm --detail /dev/md0
/dev/md0:
        Version : 1.2
  Creation Time : Fri Dec 12 18:46:33 2014
     Raid Level : raid5
     Array Size : 305664 (298.55 MiB 313.00 MB)
  Used Dev Size : 101888 (99.52 MiB 104.33 MB)
   Raid Devices : 4
  Total Devices : 4
    Persistence : Superblock is persistent

    Update Time : Fri Dec 12 19:38:26 2014
          State : clean
 Active Devices : 4
Working Devices : 4
 Failed Devices : 0
  Spare Devices : 0

         Layout : left-symmetric
     Chunk Size : 512K

           Name : ubuntu-vm:0  (local to host ubuntu-vm)
           UUID : 31c0ae28:3cc27473:5dc6bc0c:17f01003
         Events : 47

    Number   Major   Minor   RaidDevice State
       0       8       16        0      active sync   /dev/sdb
       5       8       80        1      active sync   /dev/sdf
       2       8       48        2      active sync   /dev/sdd
       4       8       64        3      active sync   /dev/sde
```

```
$ lsblk
NAME   MAJ:MIN RM   SIZE RO TYPE  MOUNTPOINT
sda      8:0    0     8G  0 disk
├─sda1   8:1    0     7G  0 part  /
├─sda2   8:2    0     1K  0 part
└─sda5   8:5    0  1022M  0 part  [SWAP]
sdb      8:16   0   100M  0 disk
└─md0    9:0    0 298.5M  0 raid5 /mnt/raid5-md0
sdc      8:32   0   100M  0 disk
sdd      8:48   0   100M  0 disk
└─md0    9:0    0 298.5M  0 raid5 /mnt/raid5-md0
sde      8:64   0   100M  0 disk
└─md0    9:0    0 298.5M  0 raid5 /mnt/raid5-md0
sdf      8:80   0   100M  0 disk
└─md0    9:0    0 298.5M  0 raid5 /mnt/raid5-md0
sr0     11:0    1  1024M  0 rom
```

The RAID array is now fully recovered and back working with four disks. Check the data on the array is intact.

```
$ cat /mnt/raid5-md0/testfile
This is a test
```

3.4. Configuring swap partitions

It may be necessary to add more **SWAP** space on a GNU/Linux system. After upgrading the RAM on a system you may want to increase the amount of SWAP space if the system runs memory hungry applications or performs memory intense operations. SWAP can be added as either an additional SWAP partition or a SWAP file. The preference is to add a partition but that may not always be possible.

3.4.1. Add a SWAP partition

```
$ sudo parted /dev/sdb
GNU Parted 2.3
Using /dev/sdb
Welcome to GNU Parted! Type 'help' to view a list of commands.

(parted) print
Model: SanDisk Ultra (scsi)
Disk /dev/sdb: 16.0GB
Sector size (logical/physical): 512B/512B
Partition Table: gpt

Number  Start   End     Size    File system  Name     Flags
 1      1049kB  8193MB  8191MB  ext4         primary
 2      8193MB  15.0GB  6807MB  fat32        primary

(parted) rm 2
Warning: Partition /dev/sdb2 is being used. Are you sure you want to continue?
Yes/No? Yes
```

```
Error: Partition(s) 2 on /dev/sdb have been written, but we have been unable to
inform the kernel of the change, probably because it/they are in use.  As a
result, the old partition(s) will remain in use.  You should reboot now before
making further changes.
Ignore/Cancel? Ignore

(parted) print
Model: SanDisk Ultra (scsi)
Disk /dev/sdb: 16.0GB
Sector size (logical/physical): 512B/512B
Partition Table: gpt

Number  Start   End     Size    File system  Name     Flags
 1      1049kB  8193MB  8191MB  ext4         primary

(parted) mkpart primary 8193 15000

(parted) quit
```

Make the new partition into a SWAP partition.

```
$ sudo mkswap /dev/sdb2
Setting up swapspace version 1, size = 6647804 KiB
no label, UUID=63e7a71a-b0c6-4a24-a227-8c16fe54236f
```

Enable the new SWAP partition.

```
$ sudo swapon /dev/sdb2
```

Add an entry to /**etc**/**fstab** to enable the SWAP partition after boot.

```
$ sudo -s
# cat << FSTAB >> /etc/fstab

# Add lines to mount /dev/sdb2 as a SWAP partition on boot

/dev/sdb2  swap  swap    defaults    0   0

FSTAB
```

Confirm the new SWAP partition is operational.

```
$ cat /proc/swaps
Filename                                Type            Size    Used    Priority
/dev/dm-2                                 partition     7942140   0       -1
/dev/sdb2                                 partition     6647804   0       -2
```

3.4.2. Add a SWAP file

Decide on the size of SWAP file required in MB (lets say 128 MB). Multiply the size (in MB) by 1024 to determine the block size 128 x 1024 = 131,072. Create the file.

```
$ sudo dd if=/dev/zero of=/swapfile bs=1024 count=131072
131072+0 records in
131072+0 records out
134217728 bytes (134 MB) copied, 0.324203 s, 414 MB/s
```

Make the new file /**swapfile** into a SWAP file.

```
$ sudo mkswap /swapfile
Setting up swapspace version 1, size = 131068 KiB
no label, UUID=1f5a5eb3-2ac2-48f6-8174-ed20aebfa4e2
```

Enable the new SWAP file.

```
$ sudo swapon /swapfile
```

Add an entry to /**etc/fstab** to enable the SWAP file after boot.

```
$ sudo -s
# cat << FSTAB >> /etc/fstab

# Add lines to mount /dev/sdb2 as a SWAP partition on boot

/swapfile  swap  swap    defaults    0   0

FSTAB
```

Confirm the new SWAP partition is operational.

```
$ cat /proc/swaps
Filename                                Type            Size    Used    Priority
/dev/dm-2                                 partition     7942140   0       -1
/dev/sdb2                                 partition     6647804   0       -2
/swapfile                                 file          131068    0       -3
```

3.5. File attributes

3.5.1. Basic permissions

Basic permissions for files are:

Permission	Description
Read	to be able to open and view the file.
Write	to overwrite or modify the file.
eXecute	to run the file as a binary.

Basic permissions for directories are:

Permission	Description
Read	to be able to view the contents of the directory.
Write	to be able to create new files/directories within the directory.
eXecute	to be able to Change Directory (**cd**) into the directory.

View permissions in the **sandbox** directory.

```
$ ls -l
total 16
-rw-r--r-- 1 lmenabrea  lmenabrea 34 Oct 21 15:54 file1.txt
-rw-r--r-- 1 lmenabrea  lmenabrea 30 Oct 21 15:55 file2.txt
-rw-r--r-- 1 lmenabrea  lmenabrea 91 Oct 24 12:36 file3.txt
-rwxr-xr-- 1 alovelace babbage  91 Oct 26 00:54 hello.sh
drwxr-xr-x 2 lmenabrea  babbage 4096 Oct 27 00:13 more_files
```

3.5.2. Default permissions

The default permissions on a GNU/Linux system are set with the **umask** command. This command takes a mask (inverse) of the permissions that will be applied to new files. The command without values will display the current mask.

```
$ umask
0022
```

In this case with a mask of **022** the default permissions will be:

Files	Directories
777	666
022	022
-	-
755	644

3.5.3. Change permissions

To change permissions of files/directories the following commands can be used:

- **chown** - change the ownership of the file/directory (need to be root to use).
- **chgrp** - change group ownership of a file or directory.
- **chmod** - change the access rights to the file or directory, such as:
  - **chmod +rx filename** - adds Read and eXecute permissions for the Owner, Group and Others.
  - **chmod g+w filename** - adds Write permissions to the group.
  - **chmod go-w filename** - removes write perms for the group as well as others.

Change the permissions on **file1.txt** to User and Group having Read and Write access and others with no access.

```
$ chmod u+rw,g+rw,o-rwx file1.txt

$ ls -l | grep file1.txt
total 20
-rw-rw---- 1 lmenabrea  lmenabrea   34 Oct 21 15:54 file1.txt
```

Instead of letters, numeric permissions can also be used.

Permissions	Description
0	no access
1	eXecute
2	Write
4	Read

For example changing file permissions to 660 will give the user

```
$ chmod 660 file2.txt

$ ls -l | grep file2.txt
total 20
-rw-rw---- 1 lmenabrea  lmenabrea   34 Oct 21 15:54 file2.txt
```

3.5.4. Special bits

3.5.4.1. setuid Bit

The set user ID (**setuid**) bit allows the specification of which user a certain program is executed as. This is invaluable when an application that needs to run as another user (i.e. 'root') when launched. An example:

```
$ sudo chown root hello.sh
$ sudo chmod +x hello.sh
$ sudo chmod +s hello.sh

$ ls -l | grep hello.sh
-rwsr-xr-x 1 root     root    91 Oct 26 00:54 hello.sh

$ whoami
lmenabrea

$ ./hello.sh
```

When **Luigi Menabrea** launched the **hello.sh** script, it has all of the rights of the **root** user despite **lmenabrea** being the owner of the process. Note the **s** instead of the **x** in the **user** section. This indicates that the **setuid** is set.

3.5.4.2. setgid Bit

The set group ID (**setgid**) allows for the enforcement of what group ownership a directory, plus all it's subdirectories and files have. i.e. If the setgid bit is set to **babbage** on a directory, any directory or file created below that directory will also have the **babbage** group ownership. This allows the setup of shared network folders that are accessible by any member of the group, and any file below that directory will maintain that group ownership.

```
$ sudo chgrp babbage more_files
$ sudo chmod g+s more_files

$ ls -l | grep more_files
drwxr-sr-x 2 lmenabrea babbage  4096 Oct 27 00:13 more_files

$ whoami
lmenabrea

$ echo "New file data" > more_files/file4.txt

$ ls -l more_files/
total 4
-rw-r--r-- 1 lmenabrea babbage 14 Oct 27 00:48 file4.txt
```

Note that the new file has the group **babbage**.

3.5.4.3. Sticky Bit

The Save Text Attribute bit (**sticky bit**) is only set on a directory. It specifies that only the owner of a file can delete their own file within the directory regardless of other permissions. In the example where **more_files** has the group **babbage** and a file created by **lmenabrea** could only be deleted by him. So Ada Lovelace who is part of the **babbage** group cannot delete.

```
$ sudo chmod +t more_files

$ ls -l | grep ^d
drwxr-sr-t 2 lmenabrea babbage  4096 Oct 27 00:48 more_files
```

Note that the other **x** permission position is replaced by **t**, the sticky bit.

3.5.4.4. Special bits using numeric permissions

This is similar to regular permissions with the addition of another digit at the front.

Permissions	Description
0	no special bit is set.
1	sticky bit is set.
2	setgid bit is set.
4	setuid bit is set.

```
$ sudo chmod 0660 file4.txt   # No special bits, RW - User, RW - Group
$ sudo chmod 3660 file4.txt   # Sticky and setgid bits, RW - User, RW - Group
$ sudo chmod 4660 file4.txt   # setuid bits, RW - User, RW - Group
```

3.6. Finding files on the file-system

There are a number of ways to find files on a GNU/Linux system. The first is the **find** command that searches through the file-system from the poing given in the command.

```
find START-POINT -name FILE-NAME -print
```

```
$ find ~/ -name hello.sh -print
/home/lmenabrea/Desktop/sandbox/hello.sh
```

Using **locate** is somewhat faster assuming the database it is using is up-to-date. Usually **cron** runs the **updatedb** utility daily which updates a database of filenames in the system. Searching this database is much faster than searching the actual file-system. The database can be updated manually with the **updatedb** command.

```
$ sudo updatedb

$ locate hello.sh
/home/lmenabrea/Desktop/sandbox/hello.sh
```

Using GREP to find a string within a file, and list the files containing the string.

```
grep [OPTIONS] PATTERN FILES-TO-SEARCH
```

-r	Recursively.
-H	Print the file name for each match.
-l	Print file names only.
-i	Ignore case.

```
$ grep -rl "The quick brown fox" ~/*
/home/lmenabrea/Desktop/sandbox/file3.txt
/home/lmenabrea/Desktop/sandbox.tar

$ grep -rH "The quick brown fox" ~/*
/home/lmenabrea/Desktop/sandbox/file3.txt:The quick brown fox jumps over the lazy

dog.
Binary file /home/lmenabrea/Desktop/sandbox.tar matches
```

3.7. Formatting file-systems

As an example plug in a USB Stick into the USB port on the computer and format it with two partitions, one as an **ext4** partition and the other as a FAT32 (**vfat**) partition. Plug in the USB Stick and tail the output of the system dmesg output to determine its device name.

```
$ dmesg | tail
[25817.293358] scsi 7:0:0:0: Direct-Access     SanDisk  Ultra           1.26
PQ: 0 ANSI: 5
[25817.294096] sd 7:0:0:0: Attached scsi generic sg2 type 0
```

```
[25817.295497] sd 7:0:0:0: [sdb] 31266816 512-byte logical blocks: (16.0 GB/14.9
GiB)
[25817.297056] sd 7:0:0:0: [sdb] Write Protect is off
[25817.297065] sd 7:0:0:0: [sdb] Mode Sense: 43 00 00 00
[25817.298075] sd 7:0:0:0: [sdb] Write cache: disabled, read cache: enabled,
doesn't support DPO or FUA
[25817.321262]  sdb: sdb1
[25817.324918] sd 7:0:0:0: [sdb] Attached SCSI removable disk
[25817.598220] EXT4-fs (sdb1): recovery complete
[25817.599850] EXT4-fs (sdb1): mounted file-system with ordered data mode. Opts:
(null)
```

Another method to find block devices is with the use of the **lsblk** command. This command lists information about all or the specified block devices by reading the information from the **sysfs** filesystem.

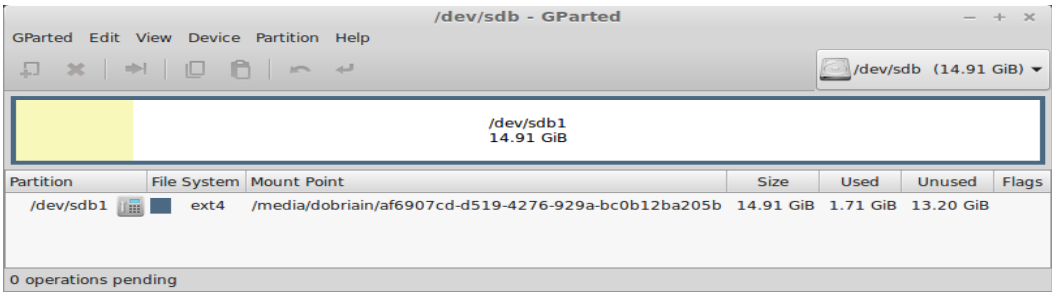
```
$ lsblk
NAME                        MAJ:MIN RM   SIZE RO TYPE  MOUNTPOINT
sda                           8:0    0 465.8G  0 disk
├─sda1                        8:1    0   243M  0 part  /boot
├─sda2                        8:2    0     1K  0 part
└─sda5                        8:5    0 465.5G  0 part
  └─sda5_crypt (dm-0)       252:0    0 465.5G  0 crypt
    ├─mint--vg-root (dm-1)  252:1    0 457.9G  0 lvm   /
    └─mint--vg-swap_1 (dm-2) 252:2   0   7.6G  0 lvm   [SWAP]
sdb                           8:16   1  14.6G  0 disk
├─sdb1                        8:17   1   7.3G  0 part
└─sdb2                        8:18   1   7.3G  0 part
sr0                          11:0    1  1024M  0 rom
```

Note that the USB Stick is **/dev/sdb1**. Run the **fdisk** utility to edit the partition table. If the existing drive was created with GUID Partition Table (GPT) layout of the partition table on the disk instead of Master Boot Record (MBR) then the **gparted** utility must be used.

```
$ sudo fdisk /dev/sdb

WARNING: GPT (GUID Partition Table) detected on '/dev/sdb'! The util fdisk
doesn't support GPT. Use GNU Parted.

Command (m for help):
```

Install **gparted**.

```
$ sudo apt-get gparted

$ sudo gparted /dev/sdb
```



gparted is a graphical utility, for command-line equivalent use **parted**.

```
$ sudo parted /dev/sdb
GNU Parted 2.3
Using /dev/sdb
Welcome to GNU Parted! Type 'help' to view a list of commands.
(parted)
```

The **print** command shows the existing partitions on the drive.

```
(parted) print
Model: SanDisk Ultra (scsi)
Disk /dev/sdb: 16.0GB
Sector size (logical/physical): 512B/512B
Partition Table: gpt

Number  Start   End     Size    File system  Name              Flags
 1      1049kB  16.0GB  16.0GB  ext4         Linux file-system

(parted) rm 1
Warning: Partition /dev/sdb1 is being used. Are you sure you want to continue?
Yes/No? Yes
Error: Partition(s) 1 on /dev/sdb have been written, but we have been unable to
inform the kernel of the change, probably because it/they are in use.  As a
result, the old partition(s) will remain in use.  You should reboot now before
making further changes.
Ignore/Cancel? Ignore
(parted) quit
Information: You may need to update /etc/fstab.
```

Umount the partition /**dev**/**sdb1** and reload by removing the USB drive and plugging it back in. Now print the partition table for /**dev**/**sdb** and you will see the table is empty.

```
$ sudo umount /dev/sdb1

$ sudo parted /dev/sdb
GNU Parted 2.3
Using /dev/sdb
Welcome to GNU Parted! Type 'help' to view a list of commands.
(parted) print
Model: SanDisk Ultra (scsi)
Disk /dev/sdb: 16.0GB
Sector size (logical/physical): 512B/512B
Partition Table: gpt

Number  Start  End  Size  File system  Name  Flags

(parted)
```

Create two partitions of roughly equal size.

```
(parted) mkpart primary 1 8192
(parted) mkpart primary 8193 15000
(parted) print
Model: SanDisk Ultra (scsi)
Disk /dev/sdb: 16.0GB
Sector size (logical/physical): 512B/512B
Partition Table: gpt

Number  Start   End     Size    File system  Name     Flags
 1      1049kB  8193MB  8191MB  ext4         primary
 2      8193MB  15.0GB  6807MB               primary

(parted) exit
```

Check the new partitions.

```
$ cat /proc/partitions | grep sdb
   8       16   15633408 sdb
   8       17    7999488 sdb1
   8       18    6647808 sdb2
```

Make an **ext4** file-system on /**dev**/**sdb1**.

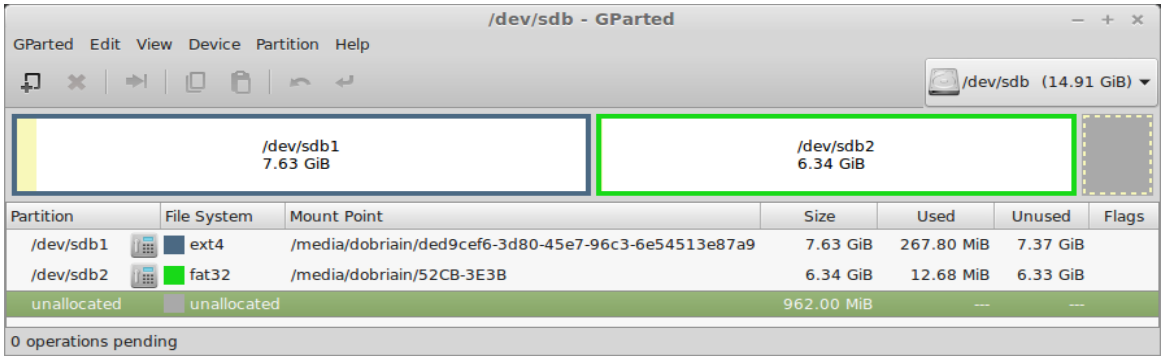
```
$ sudo mkfs.ext4 /dev/sdb1

mke2fs 1.42.9 (4-Feb-2014)
file-system label=
OS type: Linux
Block size=4096 (log=2)
Fragment size=4096 (log=2)
Stride=0 blocks, Stripe width=0 blocks
499968 inodes, 1999872 blocks
99993 blocks (5.00%) reserved for the super user
First data block=0
Maximum file-system blocks=2051014656
62 block groups
32768 blocks per group, 32768 fragments per group
8064 inodes per group
Superblock backups stored on blocks:
      32768, 98304, 163840, 229376, 294912, 819200, 884736, 1605632

Allocating group tables: done
Writing inode tables: done
Creating journal (32768 blocks): done
Writing superblocks and file-system accounting information:
```

Make a FAT32 (**vfat**) file-system on /**dev**/**sdb2**.

```
$ sudo mkfs.fat /dev/sdb2
mkfs.fat 3.0.26 (2014-03-07)
```

Display new partitions.

```
$ sudo gparted /dev/sdb
```



```
$ sudo parted /dev/sdb
GNU Parted 2.3
Using /dev/sdb
Welcome to GNU Parted! Type 'help' to view a list of commands.
(parted) print
Model: SanDisk Ultra (scsi)
Disk /dev/sdb: 16.0GB
Sector size (logical/physical): 512B/512B
Partition Table: gpt

Number  Start   End     Size    File system  Name     Flags
 1      1049kB  8193MB  8191MB  ext4         primary
 2      8193MB  15.0GB  6807MB  fat32        primary
```

3.7.1. Encrypt a partition

Starting with a standard partition of type **ext4**.

```
$ mkfs.ext4 /dev/sdb1
```

Using Linux Unified Key Setup (LUKS) as the standard for disk encryption on Linux. **luksFormat** initialises a LUKS partition and sets the initial passphrase.

```
$ sudo cryptsetup luksFormat /dev/sdb1

WARNING!
========
This will overwrite data on /dev/sdb1 irrevocably.

Are you sure? (Type uppercase yes): YES
Enter passphrase: secret
Verify passphrase: secret
```

luksOpen opens the LUKS device and sets up a mapping to a given name (i.e. secret-disk) after successful verification of the supplied passphrase.

```
$ sudo cryptsetup luksOpen /dev/sdb1 secret-disk
Enter passphrase for /dev/sdb1: secret
```

The file /**etc**/**crypttab** contains descriptive information about encrypted filesystems. **crypttab** is only read by programs like cryptdisks_start and cryptdisks_stop.

```
$ sudo vi /etc/crypttab

# <target name> <source device>         <key file>      <options>

secret-disk     /dev/sdb1
```

Note: The device can be referred to as /**dev**/**sdb** or /**dev**/**mapper**/**secret-disk**.

Make a filesystem on the new encrypted partition.

```
$ sudo mkfs.ext4 /dev/sdb1
mke2fs 1.42.9 (4-Feb-2014)
Filesystem label=
OS type: Linux
Block size=4096 (log=2)
Fragment size=4096 (log=2)
Stride=0 blocks, Stripe width=0 blocks
488640 inodes, 1953408 blocks
97670 blocks (5.00%) reserved for the super user
First data block=0
Maximum filesystem blocks=2000683008
60 block groups
32768 blocks per group, 32768 fragments per group
8144 inodes per group
Superblock backups stored on blocks:
      32768, 98304, 163840, 229376, 294912, 819200, 884736, 1605632

Allocating group tables: done
Writing inode tables: done
Creating journal (32768 blocks): done
Writing superblocks and filesystem accounting information: done
```

Make a mount point.

```
$ sudo mkdir /mnt/secret
```

Add to the /**etc**/**fstab** file.

```
$ sudo vi /etc/fstab

# Secret Disk
/dev/mapper/secret-disk    /mnt/secret    ext4    defaults    1    2
```

Mount the filesystems in the /**etc**/**fstab**.

```
$ sudo mount -a
```

Confirm.

```
$ df -h | grep secret

/dev/mapper/secret-disk  7.3G   17M  6.9G   1% /mnt/secret
```

3.8. Mounting file-systems automatically at boot time

For this example the USB Stick created earlier will be mounted automatically at boot time. Clear the **dmesg** log.

```
$ sudo dmesg -clear
```

Plug in the USB Stick and then run **dmesg**.

```
$ dmesg
[ 7574.595004] usb 1-1.2: new high-speed USB device number 7 using ehci-pci
[ 7574.688531] usb 1-1.2: New USB device found, idVendor=0781, idProduct=556c
[ 7574.688536] usb 1-1.2: New USB device strings: Mfr=1, Product=2,
SerialNumber=3
[ 7574.688539] usb 1-1.2: Product: Ultra
[ 7574.688542] usb 1-1.2: Manufacturer: SanDisk
[ 7574.688544] usb 1-1.2: SerialNumber: 20051535821900D271F3
[ 7574.688966] usb-storage 1-1.2:1.0: USB Mass Storage device detected
[ 7574.689214] scsi7 : usb-storage 1-1.2:1.0
[ 7575.687130] scsi 7:0:0:0: Direct-Access     SanDisk  Ultra            1.26
PQ: 0 ANSI: 5
[ 7575.687636] sd 7:0:0:0: Attached scsi generic sg2 type 0
[ 7575.689238] sd 7:0:0:0: [sdb] 31266816 512-byte logical blocks: (16.0 GB/14.9
GiB)
[ 7575.690942] sd 7:0:0:0: [sdb] Write Protect is off
[ 7575.690945] sd 7:0:0:0: [sdb] Mode Sense: 43 00 00 00
[ 7575.692903] sd 7:0:0:0: [sdb] Write cache: disabled, read cache: enabled,
doesn't support DPO or FUA
[ 7575.717239]  sdb: sdb1 sdb2
[ 7575.721558] sd 7:0:0:0: [sdb] Attached SCSI removable disk
[ 7576.079960] FAT-fs (sdb2): Volume was not properly unmounted. Some data may
be corrupt. Please run fsck.
[ 7576.116953] EXT4-fs (sdb1): recovery complete
[ 7576.125055] EXT4-fs (sdb1): mounted file-system with ordered data mode. Opts:
(null)
```

This confirms the device is /**dev**/**sdb**. Now check the partition table with **parted**.

```
$ sudo parted /dev/sdb
GNU Parted 2.3
Using /dev/sdb
Welcome to GNU Parted! Type 'help' to view a list of commands.
(parted) print
Model: SanDisk Ultra (scsi)
Disk /dev/sdb: 16.0GB
Sector size (logical/physical): 512B/512B
Partition Table: gpt

Number  Start   End     Size    File system  Name     Flags
 1      1049kB  8193MB  8191MB  ext4         primary
 2      8193MB  15.0GB  6807MB  fat32        primary
```

Two partitions /**dev**/**sdb1**, the **ext4** partition and /**dev**/**sdb2** the FAT32 (**vfat**) partition exist. Create directories as points in the file system to mount the partitions to.

```
$ sudo mkdir /mnt/ext4fs
$ sudo mkdir /mnt/fat32fs
```

Add entries to the /**etc**/**fstab** file to map these mounts.

```
$ sudo -s
# cat << FSTAB >> /etc/fstab

# Add lines to mount /dev/sdb1 and /dev/sdb2 on boot

/dev/sdb1  /mnt/ext4fs   ext4    defaults,users    0   0
/dev/sdb2  /mnt/fat32fs  vfat    defaults,users    0   0

FSTAB
```

The **users** option permits users that are part of the **disk** group to **mount** and **unmount** the drives.

```
$ sudo usermod -a -G disk lmenabrea
```

Now **mount** the two partitions with the mount command, which will read the entries in the /**etc**/**fstab** directory.

```
$ mount /dev/sdb1
$ mount /dev/sdb2

$ mount | grep sdb
/dev/sdb1 on /mnt/ext4fs type ext4 (rw,noexec,nosuid,nodev)
/dev/sdb2 on /mnt/fat32fs type vfat (rw,noexec,nosuid,nodev)
```

Create a file on the mounted partition, confirm the file was created. **umount** the partition and confirm file is gone. Remount again to see file is back.

```
$ echo "This is a test file on the ext4 partition." > /mnt/ext4fs/ext4-file.txt

$ ls /mnt/ext4fs/ | grep ext4-file.txt
ext4-file.txt

$ cat /mnt/ext4fs/ext4-file.txt
This is a test file on the ext4 partition.

$ umount /dev/sdb1
$ ls /mnt/ext4fs/ | grep ext4-file.txt

$ mount /dev/sdb1
$ ls /mnt/ext4fs/ | grep ext4-file.txt
ext4-file.txt
```

Reboot to confirm the partitions will mount automatically.

```
$ mount | grep sdb
/dev/sdb1 on /mnt/ext4fs type ext4 (rw,noexec,nosuid,nodev)
/dev/sdb2 on /mnt/fat32fs type vfat (rw,noexec,nosuid,nodev)

$ cat /mnt/ext4fs/ext4-file.txt
This is a test file on the ext4 partition.
```

Mounts occurred automatically and the file created on the mounted partition is accessible.

3.9. Mounting networked file-systems

3.9.1. Install Network File System (NFS)

3.9.1.1. What is NFS

NFS is a Client/Server solution that offers the ability to share the resources of a server with many clients. It is also possible to have clients without hard-drives and they **mount** a virtual hard-drive on a remote NFS Server. In this way all files are stored on the NFS Server.

3.9.1.2. NFS Server

Create /library on the Server

```
linux1:~$ mkdir library
linux1:~$ sudo ln -s /home/lmenabrea/library /library
linux1:~$ echo "This is a test file" > /library/testfile
```

Install NFS on the Server

Install the following packages on the NFS Server.

```
linux1:~$ sudo apt-get install nfs-kernel-server nfs-common rpcbind
```

Add domain to idmapd.conf

Under the line **#Domain = localdomain** add the domain name.

```
linux1:~$ vi /etc/idmapd.conf

...
Domain = obriain.com
…
```

Confirm connectivity with the Client

```
$ ping -c1 linux2.obriain.com
PING linux2.obriain.com (78.143.141.205) 56(84) bytes of data.
64 bytes from 78.143.141.205: icmp_req=1 ttl=61 time=5.51 ms

--- linux2.obriain.com ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 5.519/5.519/5.519/0.000 ms
```

Configure the NFS Server

NFS **exports** are configured in the file **`/etc/exports`**. Each line begins with the absolute path of the directory to be exported, followed by a space separated list of allowed clients and their associated options. In this case the options are:

Option	Description
rw	Allow both read and write requests on this NFS volume.
sync	Reply to requests only after the changes have been committed to stable storage.
no_subtree_check	This disables subtree checking, which has mild security implications, but can improve reliability.

```
linux1:~$ sudo -s
linux1:~# echo -e "\n# /library access" >> /etc/exports
linux1:~# echo "/library linux.obriain.com(rw,sync,fsid=0,no_subtree_check)"
>> /etc/exports

linux1:~# service nfs-kernel-server start
[ ok ] Exporting directories for NFS kernel daemon....
[ ok ] Starting NFS kernel daemon: nfsd mountd.


linux1:~# exportfs -a
linux1:~# exit
```

3.9.1.3. NFS Client

Confirm connectivity with the NFS Server

```
linux2:~$ ping -c1 linux1.obriain.com
PING linux1.obriain.com (109.106.96.158) 56(84) bytes of data.
64 bytes from 109.106.96.158: icmp_req=1 ttl=62 time=8.12 ms

--- linux1.obriain.com ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 8.122/8.122/8.122/0.000 ms
```

Install NFS on the Client

Install the following packages for a Debian GNU/Linux NFS client.

```
linux2:~$ sudo apt-get install nfs-common rpcbind
```

Add domain to idmapd.conf

As on the Server add the shared Domain name.

```
linux1:~$ vi /etc/idmapd.conf
...
Domain = obriain.com
...

linux1:~$ sudo /etc/init.d/nfs-common restart
```

Setup mount in /etc/fstab file

Add an entry in the /**etc**/**fstab** file that mounts the remote NFS Server export to a local directory /**mnt**/**library**. Establish a number of options to allow **user** Read/Write (**rw**) access and the NO Set owner User ID (**nosuid**) option to block the operation of **suid**, and **sgid** bits being transferred from files on the NFS Server. Initially using the verbose **-v** option switch with the **mount** command highlights any potential problems that may exist.

```
linux2:~$ sudo -s
linux2:~# mkdir /mnt/library

linux2:~# echo -e "\n# /Mount to linux1.obriain.com:/library" >> /etc/fstab
linux2:~# echo -e
"linux1.obriain.com:/library\t/mnt/library\tnfs\tuser,rw,nosuid\t0\t0" >>
/etc/fstab

linux2:~# mount -v linux1.obriain.com:/library

mount.nfs: timeout set for Tue May 27 20:06:59 2014
mount.nfs: trying text-based options
'vers=4,addr=109.106.96.158,clientaddr=78.143.141.205'
mount.nfs: mount(2): No such file or directory
mount.nfs: trying text-based options 'addr=109.106.96.158'
mount.nfs: prog 100003, trying vers=3, prot=6
mount.nfs: trying 109.106.96.158 prog 100003 vers 3 prot TCP port 2049
mount.nfs: prog 100005, trying vers=3, prot=17
mount.nfs: trying 109.106.96.158 prog 100005 vers 3 prot UDP port 37778
```

Users and Groups

It is essential that users have the same User ID (**UID**) and Group ID (**GID**) at each side as NFS uses the ID numbers to implement permissions. In the example below note that the permissions in both cases are **UID=1001** and **GID=1001**.

NFS Server

```
linux1:~$ id

uid=1001(lmenabrea) gid=1001(lmenabrea) groups=1001(lmenabrea)
```

NFS Client

```
linux2:~$ id

uid=1001(lmenabrea) gid=1001(lmenabrea) groups=1001(lmenabrea)
```

3.9.1.4. Testing the NFS Setup

Confirm a successful mount.

```
linux2:~$ df -h | grep library

linux1.obriain.com:/library       29G  3.3G   24G  13% /mnt/library
```

Create a file on the NFS Share from the Client, use the user **lmenabrea**.

```
linux2:~$ echo "This is a client side write test" > /mnt/library/clienttestfile
linux2:~$ cat /mnt/library/clienttestfile

This is a client side write test
```

Check the file in the /**library** directory on the Server and create a server side file for test with the user **lmenabrea**.

```
linux1:~$ cat /library/clienttestfile
This is a client side write test

linux1:~$ echo "This is a Server side write test" > /library/servertestfile
linux1:~$ cat /library/servertestfile

This is a Server side write test
```

Check the **servertestfile** on the NFS Client from the **lmenabrea** user.

```
linux2:~$ cat /mnt/library/servertestfile

This is a Server side write test
```

3.10. Partitioning storage devices

3.11. Troubleshooting file-system issues

The **fsck** utility is used to check a file-system health and should only be run against an unmounted file-system to check for possible issues.

The exit code returned by **fsck** is the sum of the following conditions:

Exit code	Meaning
0	No errors
1	file-system errors corrected
2	System should be rebooted
4	file-system errors left uncorrected
8	Operational error
16	Usage or syntax error
32	Fsck canceled by user request
128	Shared-library error

Check the EXT4 file-system on /**dev**/**sdb1** partition. Note the **echo $?** gives the exit status for the previous command.

```
$ fsck.ext4 /dev/sdb1
e2fsck 1.42.9 (4-Feb-2014)
/dev/sdb1: clean, 13/499968 files, 68558/1999872 blocks

$ echo $?
0
```

Check the FAT32 file-system on /**dev**/**sdb2** partition. **echo $?** returns an exit status of **0**.

```
$ fsck.vfat /dev/sdb2
fsck.fat 3.0.26 (2014-03-07)
/dev/sdb2: 1 files, 1/1658708 clusters

$ echo $?
0
```

If a file-system has not been cleanly unmounted, the system detects a **dirty bit** on the file-system during the next bootup and starts a check. **fsck** will detect any errors on the file-system and attempt to fix. You should not interrupt this repair process. If an empty **forcefsck** file is created in the root of the root file-system. file-systems that have > 0 specified in the sixth column of the /**etc**/**fstab** will be checked. **0** means do not check. In the case of the extract of /**etc**/**fstab** below, /**dev**/**sdb1** would be checked, however /**dev**/**sdb2** would not.

```
$ sudo touch /forcefsck

(Extract from /dev/fstab)

# <file system>  <mount point>   <type>  <options>     <dump>  <pass>
/dev/sdb1      /mnt/ext4fs     ext4    defaults          0       1
/dev/sdb2      /mnt/fat32fs    vfat    defaults          0       0
```

This page is intentionally blank

4. Local security

4.1. Accessing the root account

Substitute User (**su**) is command is used to change a login session's owner. In this example the login session of **lmenabrea** has the ownership of the session change to Ada Lovelace **alovelace**.

```
$ whoami
lmenabrea

$ su alovelace
Password: maths
:/home> whoami
alovelace

:/home> echo $PATH
/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin:/usr/games:/usr/local/
games
```

In this case Ada Lovelace will maintain the current directory and the environmental variables of the original user rather than switching to her own account directory and environment variables. To switch and change the current directory and environmental variables a **-** is required. To demonstrate, note the different $PATH values.

```
$ whoami
lmenabrea
```

Change to Ada Lovelace account. Trying with and without the '**-**' or a '**-l**' switch. Using either of these switch options provide an environment similar to what the user would expect had the user logged in directly. This can be seen by noting the **$PATH** assigned after login.

```
$ su alovelace
Password: maths

:~> whoami
alovelace

:~> echo $PATH
/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin:/usr/games:/usr/
local/games

:~> echo $HOME
/home/alovelace

$ su - alovelace
Password: maths

:~% whoami
alovelace

:~% echo $PATH
/usr/local/bin:/usr/bin:/bin:/usr/local/games:/usr/games

:~% echo $HOME
/home/alovelace
```

To change to the **root** user with Super User privileges. Again note the difference when a '**-**' or '**-l**' is used.

```
$ su
 Password: root-pass
 ~ # whoami
 root

 $ echo $PATH
 /usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin:/usr/games:/usr/
 local/games

 # echo $HOME
 /root

 $ su -
 Password: root-pass

 ~ # whoami
 root

 ~ # echo $PATH
 /usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin


 ~ # echo $HOME
 /root
```

4.2. Using sudo to manage access to the root account

SuperUser Do (**sudo**) is a program used to execute a command as another user. It allows users to run programs with the security privileges of another user (typically the superuser, or root).

Looking at a new iteration of the **hello.sh** script used earlier. Note that it is owned by **alovelace** and group rights are with the **babbage** group. Therefore any attempt by **lmenabrea** to run the script fails.

```
$ cat hello.sh
#!/bin/bash
echo "Hello World"
while :
do
  echo "Press [CTRL+C] to stop.."q
  sleep 1
done

$ ls -la | grep hello.sh
-rwxr-xr-- 1 alovelace babbage    91 Oct 26 00:54 hello.sh

$ ./hello.sh
-bash: ./hello.sh: Permission denied
```

Now run with **sudo**, you can see that the process is actually ran by the user **root**.

```
$ sudo ./hello.sh
Hello World
Press [CTRL+C] to stop..
Press [CTRL+C] to stop..
Press [CTRL+C] to stop..


root      6248  6247  0 01:00 pts/7    00:00:00 /bin/bash ./hello.sh
```

Now try running it as **alovelace** or the group **babbage** using **sudo**. In the latter case the script is ran by **lmenabrea** and is allowed because the **sudo** was supplied the group **babbage** and **lmenabrea** is in the **sudo** group.

```
$ sudo -u alovelace ./hello.sh
Hello World
Press [CTRL+C] to stop..
Press [CTRL+C] to stop..
Press [CTRL+C] to stop..


alovela+  6130  6129  0 00:58 pts/7    00:00:00 /bin/bash ./hello.sh


$ sudo -g babbage ./hello.sh
Hello World
Press [CTRL+C] to stop..
Press [CTRL+C] to stop..
Press [CTRL+C] to stop..


lmenabrea  6402  6401  0 01:02 pts/7    00:00:00 /bin/bash ./hello.sh
```

4.2.1. Who can sudo ?

The **sudo** policy is configured in the /**etc**/**sudoers** file. This is responsible for defining which users have privileges to use **sudo**.

This file also has an **includedir** that reads in all files in the /**etc**/**sudoers.d** directory and it is expected that files be added instead of editing the /**etc**/**sudoers** file directly. It has three important lines that give the user **root** and the users in the **admin** and **sudo** groups rights to **sudo** access.

```
root        ALL=(ALL:ALL) ALL
%admin      ALL=(ALL) ALL
%sudo       ALL=(ALL:ALL) ALL
```

The easiest way to give a user **sudo** rights is to add them to the **sudo** group. In this example Ada Lovelace is added to the **sudo** group and given **sudo** privileges. (It is possible to directly edit the /**etc**/**group** file either).

```
$  cat /etc/group | grep ^sudo
sudo:x:27:lmenabrea

$ sudo usermod -a -G sudo alovelace

$ cat /etc/group | grep ^sudo
sudo:x:27:lmenabrea,alovelace
```

4.2.2. root from sudo

It is possible to get full root privileges using **sudo** with the **-s** switch. This is identical to the **su** command except the **root** password is not necessary, just using the password of the regular user that has **sudo** privileges.

```
$ sudo -s
# whoami
root
```

5. Shell scripting

5.1. Basic bash shell scripting

5.1.1. Hello world

```
#!/bin/bash
echo "Hello World"
```

5.1.2. Getting input

```
#!/bin/bash
# Interactive reading of variables
echo "ENTER YOUR NAME"
read sname
# Display of variable values
echo $sname
```

5.1.3. Basic Syntax and Special Characters

Character	Description
#	Used to add a comment, except when used as \#, or as #! when starting a script
\	Used at the end of a line to indicate continuation on to the next line
;	Used to interpret what follows as a new command
$	Indicates what follows is a variable

5.1.4. Functions

```
display () {
       echo "This is a sample function"
}
```

5.1.5. Command Substitution

By enclosing the inner command with backticks (`) or by enclosing the inner command in **$( )** .

```
#!/bin/bash
ls /lib/modules/`uname -r`
echo; printf '*%.0s' {1..20}; echo
ls /lib/modules/$(uname -r)
echo
```

```
$ ./cmd_sub.sh
build kernel         modules.alias.bin  modules.builtin.bin  modules.dep.bin
modules.order    modules.symbols      updates
initrd        modules.alias  modules.builtin    modules.dep
modules.devname  modules.softdep  modules.symbols.bin

********************
build kernel         modules.alias.bin  modules.builtin.bin  modules.dep.bin
modules.order    modules.symbols      updates
initrd        modules.alias  modules.builtin    modules.dep
modules.devname  modules.softdep  modules.symbols.bin
```

5.1.6. Environment Variables

```
#!/bin/bash
DIDDLY=pink
echo "My teddybear is $DIDDLY"
```

```
$ ./pink.sh
My teddybear is pink
```

5.1.7. Exporting Variables

Variables created within a script are available only to the subsequent steps of that script. Any child processes (sub-shells) do not have automatic access to the values of these variables.

```
export VAR=value
```

or

```
VAR=value ; export VAR
```

5.1.8. Script Parameters

Parameter	Meaning
$0	Script name
$1	First parameter
$2, $3, etc.	Second, third parameter, etc.
$*	All parameters
$#	Number of arguments

5.1.9. Redirection

```
$ wc -l syslog.pdf
1721 syslog.pdf

$ wc -l < syslog.pdf
1721
```

5.1.10. if statement

```
if TEST-COMMANDS; then CONSEQUENT-COMMANDS; fi
```

A more general definition is:

```
if condition
then
       statements
else
       statements
fi
```

i.e.

```
$ cat if.sh
#!/bin/bash

echo -n "ENTER A NUMBER: "
read number

if [ $number -eq 10 ]
then
       echo 'It is 10'
else
       echo 'It is not 10'
fi

$ ./if.sh
ENTER A NUMBER: 10
It is 10

$ ./if.sh
ENTER A NUMBER: 11
It is not 10
```

5.1.11. elif statement

```
if condition
then
       statements
else
       statements
fi
```

i.e.

```
$ cat elif.sh
#!/bin/bash

echo -n "ENTER A NUMBER: "
read number

if [ $number -eq 10 ]
then
       echo 'It is 10'
elif [ $number -eq 11 ]
then
       echo 'It is 11'
else
       echo 'It is not 10 or 11'
fi


$ ./elif.sh
ENTER A NUMBER: 10
It is 10

$ ./elif.sh
ENTER A NUMBER: 11
It is 11

$ ./elif.sh
ENTER A NUMBER: 12
It is not 10 or 11
```

5.1.11.1. Using 'if' to test for files

```
if [ -f filename ]
```

Condition	Meaning
-e file	Check if the file exists.
-d file	Check if the file is a directory.
-f file	Check if the file is a regular file.
-s file	Check if the file is of non-zero size.
-g file	Check if the file has sgid set.
-u file	Check if the file has suid set.
-r file	Check if the file is readable.
-w file	Check if the file is writeable.
-x file	Check if the file is executable.

5.1.12. Comparison Operators

5.1.12.1. Numerical tests

Operator	Meaning
-eq	Equal to.
-ne	Not equal to.
-gt	Greater than.
-lt	Less than.
-ge	Greater than or equal to.
-le	Less than or equal to.

5.1.12.2. String tests

Operator	Meaning
==	Is equal to.
!=	Is not equal to.
-z	String is null.
-n	String is not null.

```
if [ string1 == string2 ] ; then
   ACTION
fi
```

5.1.13. Arithmetic Expressions

```
expr 8 + 8
echo $(expr 8 + 8)
```

Using the **$((...))** syntax: This is the built-in shell format. The syntax is as follows:

```
echo $((x+1))
```

Using the built-in shell command let. The syntax is as follows:

```
let x=( 1 + 2 ); echo $x
```

5.1.14. Strings

5.1.14.1. Length of a String

```
myLen1=${#mystring1}
```

Saves the length of mystring1 in the variable myLen1.

5.1.14.2. Parts of a string

```
${string:0:1}
```

Here 0 is the offset in the string (i.e., which character to begin from) where the extraction needs to start and 1 is the number of characters to be extracted.

```
${string#*.}
```

To extract all characters in a string after a dot (.).

5.1.15. Boolean Expressions

Operator	Operation	Meaning
&&	AND	The action will be performed only if both the conditions evaluate to true.
||	OR	The action will be performed if any one of the conditions evaluate to true.
!	NOT	The action will be performed only if the condition evaluates to false.

5.1.16. CASE statement

```
case expression in
   pattern1) execute commands;;
   pattern2) execute commands;;
   pattern3) execute commands;;
   pattern4) execute commands;;
   * )       execute some default commands or nothing ;;
esac
```

Example:

```
#!/bin/bash
echo "ENTER a number between 1 & 5"
read numb

case $numb in
    1 ) echo "you  selected 1";;
    2 ) echo "you  selected 2";;
    3 ) echo "you  selected 3";;
    4 ) echo "you  selected 4";;
    5 ) echo "you  selected 5";;
    * ) echo "you cheated !! ";;
esac
```

5.1.17. Looping Constructs

5.1.17.1. for

```
#!/bin/bash

num=0
end=15

for i in 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
do
  num=$(($num+$i))
done

echo "The sum of $end numbers is $num "

num=0

for i in {1..15}
do
  num=$(($num+$i))
done

echo "The sum of $end numbers is $num "

num=0

for (( j=$num; j<=$end; j++ ))
do
  num=$(($num+$j))
done

echo "The sum of $end numbers is $num "
```

5.1.17.2. while

```
#!/bin/bash

num=0
end=15

while [ $num -lt $end ]
do
  echo "$num is less than $end"
  ((num++))
done

echo "$num = $end"
```

5.1.17.3. until

```
#!/bin/bash

num=0
end=15

until [ $num -eq $end ]
do
  echo "$num is less than $end"
  ((num++))
done

echo "$num = $end"
```

5.1.18. Script Debugging

```
#!/bin/bash -xv
```

set -x	activate debugging from here.
cmd	Command or command block to be monitored.
set +x	stop debugging from here.

5.1.19. Redirecting Errors to File and Screen

File stream	Description	File Descriptor
stdin	Standard Input, by default the keyboard/terminal for programs run from the command line	0
stdout	Standard output, by default the screen for programs run from the command line	1
stderr	Standard error, where output error messages are shown or saved	2

5.1.20. Creating Temporary Files and Directories

Command	Usage
TEMP=$(mktemp /tmp/tempfile.XXXXXXXX)	To create a temporary file
TEMPDIR=$(mktemp -d /tmp/tempdir.XXXXXXXX)	To create a temporary directory

```
$ mktemp passwdXXXX
passwdU9t3

$ mktemp -d passwdXXXX
passwdSjnH

$ ls -l |grep pass
drwx------ 2 lmenabrea lmenabrea   4096 Oct  1 17:49 passwdSjnH
-rw------- 1 lmenabrea lmenabrea      0 Oct  1 17:49 passwdU9t3
```

5.1.21. Discarding Output with /dev/null

/**dev**/**null** the bit bucket or black hole.

5.1.22. Random Numbers and Data

```
$ echo $RANDOM
3679

$ echo $RANDOM
394

$ echo $RANDOM
16847

$ echo $RANDOM
7609
```

random, urandom kernel random number source devices.

```
$ head -c 1M < /dev/urandom > ~/Desktop/random.data.1M

$ ls -l ~/Desktop/random.data.1M
-rw-r--r-- 1 lmenabrea lmenabrea 1048576 Oct  1 19:01
/home/lmenabrea/Desktop/random.data.1M

$ cat ~/Desktop/random.data.1M

      ◆RI;◆Hl◆X0◆◆
                    ◆V◆Rs.◆◆◆◆K◆◆Ï◆◆◆e◆◆◆s4◆2"◆M◆◆◆◆EFeb◆◆◆◆E◆◆◆◆+)◆◆&◆}◆D◆◆*◆◆◆
IG◆◆◆◆◆◆4F◆◆Qw
                         ◆◆◆#◆◆E◆◆fN◆6◆y◆◆◆SO\◆`;;
◆}<◆X◆◆◆◆"I◆◆◆◆◆◆FJo◆_m◆◆◆◆◆V◆u(v◆CG◆H 9◆◆X◆◆Kx=rdD◆◆◆◆◆>&`tÍ◆4◆\◆◆.◆\:7k◆◆?
x.◆R◆O}◆◆◆+z◆◆X8◆◆◆◆◆◆c◆4◆NP◆◆◆x◆◆◆◆55◆◆ j◆E◆◆|}M◆◆4O◆r◆v◆Fk◆-◆◆0◆◆
                                                _9◆◆v◆`◆4=KA◆i◆◆◆◆◆{1◆S◆{◆E◆
WV=◆◆◆Z◆◆_◆g◆◆◆a'$◆U◆◆ ◆B/◆◆◆◆n◆◆◆◆G◆◆Ô◆Ku-◆"|◆4◆◆◆◆@◆#◆
                                                        ◆◆◆
```

5.1.23. Here Documents

A here document is a special-purpose code block. It uses a form of I/O redirection to feed a command list to an interactive program or a command.

```
$ cat <<EOM
------------------------------------
This is line 1 of the message.
This is line 2 of the message.
This is line 3 of the message.
This is line 4 of the message.
This is the last line of the message.
------------------------------------
EOM
```

Using <<- instead of << suppresses leading tabs.

```
$ cat <<-EOM
      ------------------------------------
      This is line 1 of the message.
      This is line 2 of the message.
      This is line 3 of the message.
      This is line 4 of the message.
      This is the last line of the message.
      ------------------------------------
EOM
```

Assign a here document to a variable.

```
#!/bin/bash

here_file=$(cat <<EOM
------------------------------------
This is line 1 of the message.
This is line 2 of the message.
This is line 3 of the message.
This is line 4 of the message.
This is the last line of the message.
------------------------------------
EOM
)

echo "Here is the document"; echo

echo "$here_file"
```

Using a here document as a comment block. Handy for troubleshooting.

```
: <<COMMENT
This will not be processed
by the bash interpretor.
COMMENT
```

6. Software management

6.1. Installing software packages

Software is installed on Debian based distributions using the APT utility. **apt-cache** is the tool used to search for packages in the repositories while **apt-get** is the APT tool for handling packages

```
apt-get [options] [command] [package ¼]
```

6.1.1. apt-get commands

Command	Meaning
update	used to resynchronise the package overview files from their sources.
upgrade	used to install the newest versions of all packages currently installed on the system from the sources enumerated in **/etc/apt/sources.list**.
dist-upgrade	dist-upgrade, in addition to performing the function of upgrade, also intelligently handles changing dependencies with new versions of packages.
install	install is followed by one or more packages desired for installation.
remove	to install except that packages are removed instead of installed.
check	Diagnostic tool; it updates the package cache and checks for broken packages.
clean	clean clears out the local repository of retrieved package files.

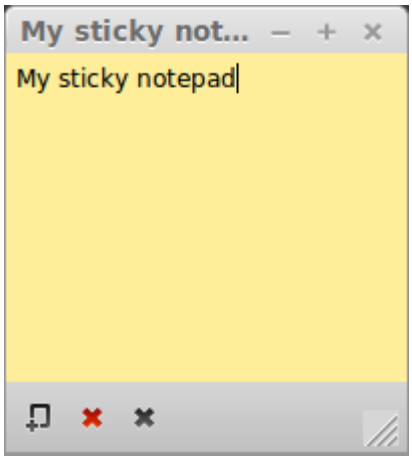
6.1.2. Example

Find a package that acts as a sticky note for the desktop and install.

```
apt-cache search <package>
```

```
$ apt-cache search sticky
knotes - sticky notes application
labrea - a "sticky" honeypot and IDS
rhinote - virtual sticky-notes for your desktop
xpad - sticky note application for X

$ sudo apt-get install xpad
```

```
$ xpad
```



7. Additional handy tools for exam

7.1. Using tmux

tmux is a terminal multiplexer: it enables a number of terminals to be created, accessed, and controlled from a single screen. **tmux** may be detached from a screen and continue running in the background, then later reattached.

7.1.1. Session Management

Shell command	Meaning
$ tmux new -s <session_name>	Creates a new tmux session named <session_name>
$ tmux attach -t <session_name>	Attaches to an existing tmux session named <session_name>
$ tmux switch -t <session_name>	Switches to an existing session named <session_name>
$ tmux list-sessions	Lists existing tmux sessions
$ tmux detach (prefix + d)	Detach the currently attached session

7.1.2. Session commands

Keystroke	Meaning
<Ctrl-b>%	Split a window vertically
<Ctrl-b>"	Split the window horizontally
<Ctrl-b>x	Kill the current pane
<Ctrl-b> Up, Down, Right, Left	Move the cursor from one pane to the other
<Ctrl-b>;	If you want to go to the previously active pane
<Ctrl-b><Ctrl-o>	Rotate the panes
<Ctrl-b>x	Close the current pane
<Ctrl-b>[	Scroll within a pane (use q to exit this mode)
<Ctrl-b>{	Swap the current pane with the previous pane
<Ctrl-b>}	Swap the current pane with the next pane

tmux is handy for the examination to create multiple shell panes.

7.2. Calculator

bc is a command-line calculator.

```
$ bc
bc 1.06.95
Copyright 1991-1994, 1997, 1998, 2000, 2004, 2006 Free Software Foundation, Inc.
This is free software with ABSOLUTELY NO WARRANTY.
For details type `warranty'.

34*4
136

23+45
68

10/5
2

66-6
60

quit
```

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Version 1.3, 3 November 2008

0. PREAMBLE

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