(b) Linux File Systems:

1. Types of Linux File System:
   - ext: The ext (extended file system) was the first file system created specifically for Linux. It has undergone several revisions, such as ext2, ext3, and ext4.
   - ext2: The second extended file system, providing improvements over the original ext.
   - ext3: An extension of ext2 with the addition of journaling, which improves file system recovery in case of a crash.
   - ext4: The fourth version of the extended file system, featuring improvements in performance, scalability, and reliability over ext3.

2. Characteristics of a File System:
   - Hierarchical Structure: Files and directories are organized in a hierarchical tree structure.
   - Permissions: Each file and directory has permission settings determining who can read, write, or execute them.
   - File Naming: Files are identified by names, and the file system supports various file attributes.
   - Journaling: Some file systems, like ext3 and ext4, use journaling to improve recovery after system crashes.
   - Inodes: Inodes store metadata about files, such as ownership, permissions, and location on disk.

3. Journaling, Versioning, and Inode:
   - Journaling: File systems like ext3 and ext4 use journaling to keep track of changes before committing them to the main file system. This helps in recovering the file system quickly after a crash.
   - Versioning: Some file systems support versioning, where multiple versions of a file can be stored and retrieved.
   - Inode (Index Node): Inodes are data structures that store information about files on disk. They contain metadata such as file ownership, permissions, timestamps, and pointers to the actual data blocks.

(c) Linux Directory Structure (File System Hierarchy):

1. `/` (root filesystem):
   - Top-level directory where the entire file system hierarchy begins.
   - Command : $ cd

2. `/root`:
   - Home directory for the root user.
   - command : $ ls at root or $ cd ../..

3. `/home`:
   - Home directories for regular users.
   - command : ls at root or $ cd ..

```
primus@primus:~/Documents/Semester6/Inf...   ×          primus@primus:/          ×

[primus@primus ~]$ ls
auto-cpufreq  Downloads              GNS3   Pictures  Public     Videos
Documents     Fedora-Dockerfiles  Music  Postman   Templates
[primus@primus ~]$ cd ..
[primus@primus home]$ ls
primus
[primus@primus home]$ cd ..
[primus@primus /]$ ls
afs  boot  etc   lib     lost+found  mnt  proc  run   srv  tmp  var
bin  dev   home  lib64   media       opt  root  sbin  sys  usr
[primus@primus /]$ 
```

4. `/boot`:
   - Contains the Linux kernel and files required for the system's initial boot process.
   - command :

```
primus@primus:~/Documents/Semester6/Inf...   ×          primus@primus:/boot          ×

primus
[primus@primus home]$ cd ..
[primus@primus /]$ ls
afs  boot  etc   lib     lost+found  mnt  proc  run   srv  tmp  var
bin  dev   home  lib64   media       opt  root  sbin  sys  usr
[primus@primus /]$ cd boot
[primus@primus boot]$ ls
config-6.5.11-300.fc39.x86_64
config-6.6.11-200.fc39.x86_64
config-6.6.6-200.fc39.x86_64
efi
grub2
initramfs-0-rescue-cb55580bc30f41fd93c11444259b8d36.img
initramfs-6.5.11-300.fc39.x86_64.img
initramfs-6.6.11-200.fc39.x86_64.img
initramfs-6.6.6-200.fc39.x86_64.img
loader
symvers-6.5.11-300.fc39.x86_64.xz
symvers-6.6.11-200.fc39.x86_64.xz
symvers-6.6.6-200.fc39.x86_64.xz
System.map-6.5.11-300.fc39.x86_64
System.map-6.6.11-200.fc39.x86_64
System.map-6.6.6-200.fc39.x86_64
vmlinuz-0-rescue-cb55580bc30f41fd93c11444259b8d36
vmlinuz-6.5.11-300.fc39.x86_64
vmlinuz-6.6.11-200.fc39.x86_64
vmlinuz-6.6.6-200.fc39.x86_64
[primus@primus boot]$ 
```

5. `/etc`:
    - Configuration files for system-wide settings.
    - command : ls at root

```
[primus@primus /]$ cd etc
[primus@primus etc]$ ls
abrt                        init.d                  pulse
adjtime                     inittab                 qemu
aliases                     inputrc                 qemu-ga
alsa                        ipp-usb                 rc0.d
alternatives                iproute2                rc1.d
anaconda                    iscsi                   rc2.d
anthy-unicode.conf          issue                   rc3.d
appstream.conf              issue.d                 rc4.d
apt                         issue.net               rc5.d
asound.conf                 java                    rc6.d
audit                       jvm                     rc.d
authselect                  jvm-common              reader.conf.d
avahi                       kdump                   redhat-release
bash_completion.d           kdump.conf              request-key.conf
bashrc                      kernel                  request-key.d
bindresvport.blacklist      keys                    resolv.conf
binfmt.d                    krb5.conf               rhashrc
bluetooth                   krb5.conf.d             ros
brlapi.key                  ld.so.cache             rpc
brltty                      ld.so.conf              rpm
brltty.conf                 ld.so.conf.d            rsyncd.conf
ceph                        libaudit.conf           rwtab.d
chkconfig.d                 libblockdev             rygel.conf
chromium                    libibverbs.d            samba
chrony.conf                 libnl                   sane.d
cifs-utils                  libreport               sasl2
common-lisp                 libssh                  sbcl.rc
containerd                  libuser.conf            security
```

6. `/bin`:
   - Essential binary files (commands) required for system recovery.
   - command : ls at root

```
vmlinuz-6.6.6-200.fc39.x86_64
[primus@primus boot]$ cd ..
[primus@primus /]$ cd bin
[primus@primus bin]$ ls
'['                                       nl
 2to3                                     nl-addr-add
 2to3-3.12                                nl-addr-delete
 7za                                      nl-addr-list
 ab                                       nl-class-add
 abrt                                     nl-class-delete
 abrt-action-analyze-backtrace           nl-classid-lookup
 abrt-action-analyze-c                   nl-class-list
 abrt-action-analyze-ccpp-local          nl-cls-add
 abrt-action-analyze-java                nl-cls-delete
 abrt-action-analyze-oops                nl-cls-list
 abrt-action-analyze-python              nl-fib-lookup
 abrt-action-analyze-vmcore              nl-link-enslave
 abrt-action-analyze-vulnerability       nl-link-ifindex2name
 abrt-action-analyze-xorg                nl-link-list
 abrt-action-check-oops-for-alt-component  nl-link-name2ifindex
 abrt-action-check-oops-for-hw-error     nl-link-release
 abrt-action-find-bodhi-update           nl-link-set
 abrt-action-generate-backtrace          nl-link-stats
 abrt-action-generate-core-backtrace     nl-list-caches
 abrt-action-list-dsos                   nl-list-sockets
 abrt-action-notify                      nl-monitor
 abrt-action-save-package-data           nl-neigh-add
 abrt-action-trim-files                  nl-neigh-delete
 abrt-applet                             nl-neigh-list
 abrt-bodhi                              nl-neightbl-list
```

7. `/sbin`:
   - System binaries, often used by the system administrator for maintenance tasks.
   - command : ls at root

```
  primus@primus:~/Documents/Semester6/Inf...  ×          primus@primus:/sbin                    ×
[primus@primus /]$ ls
afs  boot   etc    lib     lost+found  mnt   proc  run   srv   tmp  var
bin  dev    home   lib64   media       opt   root  sbin  sys   usr
[primus@primus /]$ cd sbin
[primus@primus sbin]$ ls
abrt-auto-reporting          mii-tool
abrtd                        mkdict
abrt-dbus                    mkdosfs
abrt-harvest-pstoreoops      mkdumprd
abrt-harvest-vmcore          mke2fs
abrt-server                  mkfs
accessdb                     mkfs.btrfs
accton                       mkfs.cramfs
adcli                        mkfs.exfat
addgnupghome                 mkfs.ext2
addpart                      mkfs.ext3
adduser                      mkfs.ext4
agetty                       mkfs.f2fs
alsactl                      mkfs.fat
alsa-info.sh                 mkfs.hfsplus
alternatives                 mkfs.minix
anaconda                     mkfs.msdos
apachectl                    mkfs.nilfs2
applygnupgdefaults           mkfs.ntfs
arp                          mkfs.udf
arpd                         mkfs.vfat
arping                       mkfs.xfs
arptables                    mkhomedir_helper
arptables-nft                mklost+found
```

8. `/usr`:
   - Secondary hierarchy containing user-related programs, libraries, and documentation.
   - command : ls at root

```
[primus@primus /]$ cd usr
[primus@primus usr]$ ls
bin     i686-w64-mingw32  lib     libexec  sbin    src   x86_64-w64-mingw32
games   include           lib64   local    share   tmp
[primus@primus usr]$
```

9. `/var`:
   - Variable files, such as logs, spool files, and temporary files.
   - command : ls at root

10. `/dev`:
   - Device files representing hardware devices.

```
adm      crash  empty  games  lib       lock   mail  opt  run          tmp      yp
[primus@primus var]$ cd ..
[primus@primus /]$ cd dev
[primus@primus dev]$ ls
acpi_thermal_rel  initctl       port      tty13  tty39  tty7   ttyS31       vcsa4
autofs            input         ppp       tty14  tty4   tty8   ttyS4        vcsa5
block             kmsg          ptmx      tty15  tty40  tty9   ttyS5        vcsa6
bsg               kvm           pts       tty16  tty41  ttyS0  ttyS6        vcsu
btrfs-control     log           random    tty17  tty42  ttyS1  ttyS7        vcsu1
bus               loop-control  rfkill    tty18  tty43  ttyS10 ttyS8        vcsu2
char              lp0           rtc       tty19  tty44  ttyS11 ttyS9        vcsu3
console           lp1           rtc0      tty2   tty45  ttyS12 udmabuf      vcsu4
core              lp2           sda       tty20  tty46  ttyS13 uhid         vcsu5
cpu               lp3           sda1      tty21  tty47  ttyS14 uinput       vcsu6
cpu_dma_latency   mapper        sda2      tty22  tty48  ttyS15 urandom      vfio
cuse              mcelog        sda3      tty23  tty49  ttyS16 usb          vga_arbiter
disk              media0        sda4      tty24  tty5   ttyS17 usbmon0      vhci
dma_heap          mei0          sg0       tty25  tty50  ttyS18 usbmon1      vhost-net
dri               mem           shm       tty26  tty51  ttyS19 usbmon2      vhost-vsock
drm_dp_aux0       mqueue        snapshot  tty27  tty52  ttyS2  userfaultfd  video0
fb0               net           snd       tty28  tty53  ttyS20 v4l          video1
fd                ng0n1         stderr    tty29  tty54  ttyS21 vcs          watchdog
full              null          stdin     tty3   tty55  ttyS22 vcs1         watchdog0
fuse              nvme0         stdout    tty30  tty56  ttyS23 vcs2         wmi
gpiochip0         nvme0n1       tpm0      tty31  tty57  ttyS24 vcs3         zero
hidraw0           nvme0n1p1     tpmrm0    tty32  tty58  ttyS25 vcs4         zram0
hidraw1           nvme0n1p2     tty       tty33  tty59  ttyS26 vcs5
hidraw2           nvme0n1p3     tty0      tty34  tty6   ttyS27 vcs6
hidraw3           nvme0n1p4     tty1      tty35  tty60  ttyS28 vcsa
hpet              nvme0n1p5     tty10     tty36  tty61  ttyS29 vcsa1
hugepages         nvme0n1p6     tty11     tty37  tty62  ttyS3  vcsa2
```

11. `/lib`:
   - Essential shared libraries and kernel modules.

```
hugepages          nvme0n1p6     tty11     tty37   tty62   ttyS3    vcsa2
hwrng              nvram         tty12     tty38   tty63   ttyS30   vcsa3
[primus@primus dev]$ cd ..
[primus@primus /]$ cd lib
[primus@primus lib]$ ls
abrt-java-connector                  libmenu.so.6.4
alsa                                 libmenuw.so.6
alsa-lib                             libmenuw.so.6.4
audit                                libmount.so.1
bfd-plugins                          libmount.so.1.1.0
binfmt.d                             libmp3lame.so.0
common-lisp                          libmp3lame.so.0.0.0
cpp                                  libmpg123.so.0
credstore                            libmpg123.so.0.47.0
cups                                 libm.so.6
debug                                libncurses.so.6
docker                               libncurses.so.6.4
dracut                               libncursesw.so.6
dri                                  libncursesw.so.6.4
eclipse                              libnettle.so.8
engines-3                            libnettle.so.8.8
environment.d                        libnghttp2.so.14
fedora-release                       libnghttp2.so.14.24.3
fedora-third-party                   libnm.so.0
firewalld                            libnm.so.0.1.0
firmware                             libnspr4.so
fontconfig                           libnss3.so
gallium-pipe                         libnss_compat.so.2
games                                libnss_dns.so.2
gcc                                  libnss_files.so.2
gconv                                libnss_myhostname.so.2
```

12. `/mnt`:
   - Temporary mount points for mounting external file systems.

```
[primus@primus lib]$ cd ..
[primus@primus /]$ cd mnt
[primus@primus mnt]$ ls
[primus@primus mnt]$ ls
[primus@primus mnt]$
```

13. `/media`:
   - Mount points for removable media such as USB drives.

```
[primus@primus mnt]$ ls
[primus@primus mnt]$ cd ..
[primus@primus /]$ cd media/
[primus@primus media]$ ls
[primus@primus media]$
```

14. `/opt`:
   - Optional application software packages.

```
[primus@primus media]$ cd ..
[primus@primus /]$ cd opt
[primus@primus opt]$ ls
auto-cpufreq   containerd   docker-desktop
[primus@primus opt]$ 
```

15. `/tmp`:
   - Temporary files, typically cleared on system reboot.

```
[primus@primus /]$ cd tmp
[primus@primus tmp]$ ls
dbus-1Rh7AS6u
dbus-o2F2C4YN
evince-5592
hsperfdata_primus
qemu-console1157508059
qemu-console1603509223
qemu-console3385192946
qemu-console826507703
qemu-console827752884
scoped_dirJD5Mjo
systemd-private-91d842bda91d4144b74b88060438172d-bluetooth.service-tVsNDt
systemd-private-91d842bda91d4144b74b88060438172d-chronyd.service-vJMoGo
systemd-private-91d842bda91d4144b74b88060438172d-colord.service-7nyxav
systemd-private-91d842bda91d4144b74b88060438172d-dbus-broker.service-X7xF2P
systemd-private-91d842bda91d4144b74b88060438172d-low-memory-monitor.service-QwlIMj
systemd-private-91d842bda91d4144b74b88060438172d-ModemManager.service-Km5gAl
systemd-private-91d842bda91d4144b74b88060438172d-polkit.service-oyGKFK
systemd-private-91d842bda91d4144b74b88060438172d-power-profiles-daemon.service-5yLGAI
systemd-private-91d842bda91d4144b74b88060438172d-rtkit-daemon.service-UcQUCj
systemd-private-91d842bda91d4144b74b88060438172d-switcheroo-control.service-m3nf73
systemd-private-91d842bda91d4144b74b88060438172d-systemd-logind.service-XyXsQB
systemd-private-91d842bda91d4144b74b88060438172d-systemd-oomd.service-m81Y1d
systemd-private-91d842bda91d4144b74b88060438172d-systemd-resolved.service-AIWbkf
systemd-private-91d842bda91d4144b74b88060438172d-upower.service-vKVSWE
ubuntu-20.04.6-desktop-amd64.iso-7DORH2
ubuntu-22.04-latest-desktop-amd64.iso-TBTJH2
ubuntu-23.10.1-desktop-amd64.iso-5N3VH2
[primus@primus tmp]$ 
```