CS342 Operating Systems

Homework 1

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1) I have read the first 2 chapters of the book.

2) I have chosen to install linux as a virtual machine to VirtualBox since there was not enough space left in my computer to install the operating system directly to hardware. The reason that I choose VirtualBox is because it was free software. I had Ubuntu installed as a Virtual Machine before that was version 20.04 but after realizing that the required version is 22.04, I installed that Ubuntu version as well to my VirtualBox In my installations I preferred Ubuntu Server instead of the GUI ones because I prefer to use only the terminal in the development.

The below is the list of the 10 Linux commands that I have learned.

- cd: Used to navigate through directories
- ls: Used to list directories
- pwd: Used to print working directory
- mkdir: Used to create directories
- mv: Used to move or rename files
- rm: Used to delete files or directories
- touch: Used to create empty files
- cat: Used to display file contents on the terminal
- whoami: Used to get the active username
- chmod: Used to change file permissions

3)

- The Kernel executable file resides in /boot directory and the executable file is called vmlinuz.
- The version number of my running kernel is 5.15.0-58.

4) Subdirectories:
- arch
- block
- certs
- crypto
- Documentation
- drivers
- fs
- include
- init
- io_uring
- ipc
- kernel
- lib
- LICENSES
- mm
- net
- samples
- scripts
- security
- sound
- tools
- usr
- virt

5)

- Path: linux-5.15.95/arch/x86/entry/syscalls/syscall_64.tbl

        0: read
        1: write
        2: open
        3: close
        4: stat
        5: fstat
        6: lstat
        39: getpid
        120: getresgid
        150: munlock

6)

- Sample output of the command strace ls is below:

execve("/usr/bin/ls", ["ls"], 0x7ffced99aff0 /* 25 vars */) = 0
brk(NULL)   = 0x557c4027a000
arch_prctl(0x3001 /* ARCH_??? */, 0x7ffecea623c0) = -1 EINVAL (Invalid argument)
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7fac73921000
access("/etc/ld.so.preload", R_OK)   = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/etc/ld.so.cache", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=25355, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 25355, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fac7391a000
close(3)   = 0
openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libselinux.so.1", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\0\0\0\0\0\0\0\0"..., 832) = 832
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=166280, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 177672, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7fac738ee000
mprotect(0x7fac738f4000, 139264, PROT_NONE) = 0
mmap(0x7fac738f4000, 106496, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|
MAP_DENYWRITE, 3, 0x6000) = 0x7fac738f4000
mmap(0x7fac7390e000, 28672, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x20000) = 0x7fac7390e000
mmap(0x7fac73916000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|
MAP_DENYWRITE, 3, 0x27000) = 0x7fac73916000
mmap(0x7fac73918000, 5640, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|
MAP_ANONYMOUS, -1, 0) = 0x7fac73918000
close(3)   = 0
openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libc.so.6", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\3\0\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0P\237\2\0\0\0\0\0"..., 832) = 832
pread64(3, "\6\0\0\0\4\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0"..., 784, 64) = 784
pread64(3, "\4\0\0\0 \0\0\0\5\0\0\0GNU\0\2\0\0\300\4\0\0\3\0\0\0\0\0\0\0"..., 48, 848) = 48
pread64(3, "\4\0\0\0\24\0\0\0\3\0\0\0GNU\0i8\235HZ\227\223\333\350s\360\352,\223\340."...,
68, 896) = 68
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=2216304, ...}, AT_EMPTY_PATH) = 0
pread64(3, "\6\0\0\0\4\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0"..., 784, 64) = 784
mmap(NULL, 2260560, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7fac736c6000
mmap(0x7fac736ee000, 1658880, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|
MAP_DENYWRITE, 3, 0x28000) = 0x7fac736ee000
mmap(0x7fac73883000, 360448, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x1bd000) = 0x7fac73883000
mmap(0x7fac738db000, 24576, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|
MAP_DENYWRITE, 3, 0x214000) = 0x7fac738db000

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mmap(0x7fac738e1000, 52816, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|
MAP_ANONYMOUS, -1, 0) = 0x7fac738e1000
close(3)                      = 0
openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libpcre2-8.so.0", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\0\0\0\0\0\0\0\0"..., 832) = 832
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=613064, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 615184, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7fac7362f000
mmap(0x7fac73631000, 438272, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|
MAP_DENYWRITE, 3, 0x2000) = 0x7fac73631000
mmap(0x7fac7369c000, 163840, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x6d000) = 0x7fac7369c000
mmap(0x7fac736c4000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|
MAP_DENYWRITE, 3, 0x94000) = 0x7fac736c4000
close(3)                      = 0
mmap(NULL, 12288, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) =
0x7fac7362c000
arch_prctl(ARCH_SET_FS, 0x7fac7362c800) = 0
set_tid_address(0x7fac7362cad0)        = 5467
set_robust_list(0x7fac7362cae0, 24)    = 0
rseq(0x7fac7362d1a0, 0x20, 0, 0x53053053) = 0
mprotect(0x7fac738db000, 16384, PROT_READ) = 0
mprotect(0x7fac736c4000, 4096, PROT_READ) = 0
mprotect(0x7fac73916000, 4096, PROT_READ) = 0
mprotect(0x557c3ffc0000, 4096, PROT_READ) = 0
mprotect(0x7fac7395b000, 8192, PROT_READ) = 0
prlimit64(0, RLIMIT_STACK, NULL, {rlim_cur=8192*1024, rlim_max=RLIM64_INFINITY}) = 0
munmap(0x7fac7391a000, 25355)          = 0
statfs("/sys/fs/selinux", 0x7ffecea62400) = -1 ENOENT (No such file or directory)
statfs("/selinux", 0x7ffecea62400)     = -1 ENOENT (No such file or directory)
getrandom("\x38\x88\x10\x1c\x6b\xe6\x4d\x7c", 8, GRND_NONBLOCK) = 8
brk(NULL)                     = 0x557c4027a000
brk(0x557c4029b000)           = 0x557c4029b000
openat(AT_FDCWD, "/proc/filesystems", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0444, st_size=0, ...}, AT_EMPTY_PATH) = 0
read(3, "nodev\tsysfs\nnodev\ttmpfs\nnodev\tbd"..., 1024) = 385
read(3, "", 1024)             = 0
close(3)                      = 0
access("/etc/selinux/config", F_OK)    = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/locale-archive", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=3048928, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 3048928, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fac73343000
close(3)                      = 0
openat(AT_FDCWD, "/usr/share/locale/locale.alias", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=2996, ...}, AT_EMPTY_PATH) = 0
read(3, "# Locale name alias data base.\n#"..., 4096) = 2996
read(3, "", 4096)             = 0
close(3)                      = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_IDENTIFICATION", O_RDONLY|O_CLOEXEC) =
-1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_IDENTIFICATION", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=258, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 258, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fac7395a000
close(3)                      = 0
openat(AT_FDCWD, "/usr/lib/x86_64-linux-gnu/gconv/gconv-modules.cache", O_RDONLY) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=27002, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 27002, PROT_READ, MAP_SHARED, 3, 0) = 0x7fac7391a000
close(3)                      = 0
futex(0x7fac738e0a6c, FUTEX_WAKE_PRIVATE, 2147483647) = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_MEASUREMENT", O_RDONLY|O_CLOEXEC) =
-1 ENOENT (No such file or directory)
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openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_MEASUREMENT", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=23, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 23, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fac73342000
close(3)                        = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_TELEPHONE", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_TELEPHONE", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=47, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 47, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fac73341000
close(3)                        = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_ADDRESS", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_ADDRESS", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=127, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 127, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fac73340000
close(3)                        = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_NAME", O_RDONLY|O_CLOEXEC) = -1 ENOENT
(No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_NAME", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=62, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 62, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fac7333f000
close(3)                        = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_PAPER", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_PAPER", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=34, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 34, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fac7333e000
close(3)                        = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_MESSAGES", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_MESSAGES", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFDIR|0755, st_size=4096, ...}, AT_EMPTY_PATH) = 0
close(3)                        = 0
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_MESSAGES/SYS_LC_MESSAGES", O_RDONLY|
O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=48, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 48, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fac7333d000
close(3)                        = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_MONETARY", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_MONETARY", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=270, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 270, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fac7333c000
close(3)                        = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_COLLATE", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_COLLATE", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=1406, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 1406, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fac7333b000
close(3)                        = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_TIME", O_RDONLY|O_CLOEXEC) = -1 ENOENT
(No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_TIME", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=3360, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 3360, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fac7333a000
close(3)                        = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_NUMERIC", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_NUMERIC", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=50, ...}, AT_EMPTY_PATH) = 0
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mmap(NULL, 50, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fac73339000
close(3)                      = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_CTYPE", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_CTYPE", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=353616, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 353616, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fac732e2000
close(3)                      = 0
ioctl(1, TCGETS, {B9600 opost isig icanon echo ...}) = 0
ioctl(1, TIOCGWINSZ, {ws_row=36, ws_col=120, ws_xpixel=840, ws_ypixel=504}) = 0
openat(AT_FDCWD, ".", O_RDONLY|O_NONBLOCK|O_CLOEXEC|O_DIRECTORY) = 3
newfstatat(3, "", {st_mode=S_IFDIR|0700, st_size=4096, ...}, AT_EMPTY_PATH) = 0
getdents64(3, 0x557c402834b0 /* 13 entries */, 32768) = 424
getdents64(3, 0x557c402834b0 /* 0 entries */, 32768) = 0
close(3)                      = 0
newfstatat(1, "", {st_mode=S_IFCHR|0600, st_rdev=makedev(0x88, 0x2), ...}, AT_EMPTY_PATH) =
0
write(1, "snap  test_projects\n", 20snap  test_projects
)   = 20
close(1)                      = 0
close(2)                      = 0
exit_group(0)                 = ?
+++ exited with 0 +++
```

- Sample output of the command strace pwd is below:

```
execve("/usr/bin/pwd", ["pwd"], 0x7fffa1759040 /* 25 vars */) = 0
brk(NULL)                     = 0x55936be38000
arch_prctl(0x3001 /* ARCH_??? */, 0x7fff17286f30) = -1 EINVAL (Invalid argument)
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) =
0x7fa78fead000
access("/etc/ld.so.preload", R_OK)      = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/etc/ld.so.cache", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=25355, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 25355, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fa78fea6000
close(3)                      = 0
openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libc.so.6", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\3\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0P\237\2\0\0\0\0\0"..., 832) = 832
pread64(3, "\6\0\0\0\4\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0"..., 784, 64) = 784
pread64(3, "\4\0\0\0 \0\0\0\5\0\0\0GNU\0\2\0\0\300\4\0\0\0\3\0\0\0\0\0\0\0"..., 48, 848) = 48
pread64(3, "\4\0\0\0\24\0\0\0\3\0\0\0GNU\0i8\235HZ\227\223\333\350s\360\352,\223\340."...,
68, 896) = 68
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=2216304, ...}, AT_EMPTY_PATH) = 0
pread64(3, "\6\0\0\0\4\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0"..., 784, 64) = 784
mmap(NULL, 2260560, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7fa78fc7e000
mmap(0x7fa78fca6000, 1658880, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|
MAP_DENYWRITE, 3, 0x28000) = 0x7fa78fca6000
mmap(0x7fa78fe3b000, 360448, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x1bd000) = 0x7fa78fe3b000
mmap(0x7fa78fe93000, 24576, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|
MAP_DENYWRITE, 3, 0x214000) = 0x7fa78fe93000
mmap(0x7fa78fe99000, 52816, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|
MAP_ANONYMOUS, -1, 0) = 0x7fa78fe99000
close(3)                      = 0
mmap(NULL, 12288, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) =
0x7fa78fc7b000
arch_prctl(ARCH_SET_FS, 0x7fa78fc7b740) = 0
set_tid_address(0x7fa78fc7ba10)         = 5479
set_robust_list(0x7fa78fc7ba20, 24)     = 0
rseq(0x7fa78fc7c0e0, 0x20, 0, 0x53053053) = 0
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mprotect(0x7fa78fe93000, 16384, PROT_READ) = 0
mprotect(0x55936b439000, 4096, PROT_READ) = 0
mprotect(0x7fa78fee7000, 8192, PROT_READ) = 0
prlimit64(0, RLIMIT_STACK, NULL, {rlim_cur=8192*1024, rlim_max=RLIM64_INFINITY}) = 0
munmap(0x7fa78fea6000, 25355)         = 0
getrandom("\x08\xdc\x12\x39\xf4\x16\x11\x90", 8, GRND_NONBLOCK) = 8
brk(NULL)                    = 0x55936be38000
brk(0x55936be59000)              = 0x55936be59000
openat(AT_FDCWD, "/usr/lib/locale/locale-archive", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=3048928, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 3048928, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fa78f992000
close(3)                     = 0
openat(AT_FDCWD, "/usr/share/locale/locale.alias", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=2996, ...}, AT_EMPTY_PATH) = 0
read(3, "# Locale name alias data base.\n#"..., 4096) = 2996
read(3, "", 4096)            = 0
close(3)                    = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_IDENTIFICATION", O_RDONLY|O_CLOEXEC) =
-1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_IDENTIFICATION", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=258, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 258, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fa78fee6000
close(3)                    = 0
openat(AT_FDCWD, "/usr/lib/x86_64-linux-gnu/gconv/gconv-modules.cache", O_RDONLY) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=27002, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 27002, PROT_READ, MAP_SHARED, 3, 0) = 0x7fa78fea6000
close(3)                    = 0
futex(0x7fa78fe98a6c, FUTEX_WAKE_PRIVATE, 2147483647) = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_MEASUREMENT", O_RDONLY|O_CLOEXEC) =
-1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_MEASUREMENT", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=23, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 23, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fa78f991000
close(3)                    = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_TELEPHONE", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_TELEPHONE", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=47, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 47, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fa78f990000
close(3)                    = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_ADDRESS", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_ADDRESS", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=127, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 127, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fa78f98f000
close(3)                    = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_NAME", O_RDONLY|O_CLOEXEC) = -1 ENOENT
(No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_NAME", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=62, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 62, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fa78f98e000
close(3)                    = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_PAPER", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_PAPER", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=34, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 34, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fa78f98d000
close(3)                    = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_MESSAGES", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
```

openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_MESSAGES", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFDIR|0755, st_size=4096, ...}, AT_EMPTY_PATH) = 0
close(3)   = 0
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_MESSAGES/SYS_LC_MESSAGES", O_RDONLY|
O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=48, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 48, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fa78f98c000
close(3)   = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_MONETARY", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_MONETARY", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=270, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 270, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fa78f98b000
close(3)   = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_COLLATE", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_COLLATE", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=1406, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 1406, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fa78f98a000
close(3)   = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_TIME", O_RDONLY|O_CLOEXEC) = -1 ENOENT
(No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_TIME", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=3360, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 3360, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fa78f989000
close(3)   = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_NUMERIC", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_NUMERIC", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=50, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 50, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fa78f988000
close(3)   = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_CTYPE", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_CTYPE", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=353616, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 353616, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fa78f931000
close(3)   = 0
getcwd("/root", 4096)   = 6
newfstatat(1, "", {st_mode=S_IFCHR|0600, st_rdev=makedev(0x88, 0x2), ...}, AT_EMPTY_PATH) =
0
write(1, "/root\n", 6/root
)   = 6
close(1)   = 0
close(2)   = 0
exit_group(0)   = ?
+++ exited with 0 +++

7)

Meanings of the terms:

- sys time: It is the CPU time that is spent in the kernel mode during the execution.
- user time: It is the CPU time that is spent in the user mode during the execution.
- real time: It is the time elapsed from the beginning of the execution until the end of the
  execution.

Sample Outputs:

- Below is the sample output for time ls command:

```
real    0m0.012s
user    0m0.009s
sys     0m0.002s
```

- Below is the sample output for time whoami command:

```
real    0m0.003s
user    0m0.002s
sys     0m0.001s
```

8)

- list.c:

```c
#include <stdio.h>
#include <stdlib.h>
#include <sys/time.h>
#include <time.h>

struct Node {
    int value;
    struct Node* next;
    struct Node* prev;
};

void freeMemory(struct Node* head);
void printLinkedList(struct Node* head);
struct Node* generateLinkedList(const int linkedListSize);
void sortedInsert(struct Node** headRef, struct Node* newNode);

int main() {
    struct timeval start_time;
    struct timeval end_time;
    const int NODE_COUNT = 10000;
    struct Node* head = NULL;

    srand(time(0));
    gettimeofday(&start_time, NULL);
    head = generateLinkedList(NODE_COUNT);
    gettimeofday(&end_time, NULL);

    printf("Elapsed Time (microseconds): %ld\n", (end_time.tv_usec - start_time.tv_usec));
    printLinkedList(head);
    freeMemory(head);
    return 0;
}

 // Helper Functions
void freeMemory(struct Node* head) {
    while (head != NULL) {
        struct Node* newNode = head->next;
        free(head);
        head = newNode;
    }
}
```

```c
void printLinkedList(struct Node* head) {
    struct Node* tail = NULL;
    while (head != NULL) {
        struct Node* newNode = head->next;
        printf("value = %d\n", head->value);
        head = newNode;
    }
}

struct Node* generateLinkedList(const int linkedListSize) {
    struct Node* head = NULL;
    struct Node* newNode = (struct Node*)malloc(sizeof(struct Node));
    newNode->value = rand();
    newNode->next = NULL;
    newNode->prev = NULL;

    for (int i = 1; i < linkedListSize; i++) {
        sortedInsert(&head, newNode);
        newNode = (struct Node*)malloc(sizeof(struct Node));
        newNode->value = rand();
        newNode->next = NULL;
        newNode->prev = NULL;
    }

    return head;
}

void sortedInsert(struct Node** headRef, struct Node* newNode) {
    struct Node* current;

    if (*headRef == NULL || (*headRef)->value >= newNode->value) {
        if (*headRef != NULL) {
            (*headRef)->prev = newNode;
        }
        newNode->next = *headRef;
        *headRef = newNode;
    }

    else {
        current = *headRef;
        while (current->next != NULL && current->next->value < newNode->value) {
            current = current->next;
        }
        newNode->next = current->next;
        if (current->next != NULL) {
            current->next->prev = newNode;
        }
        newNode->prev = current;
        current->next = newNode;
    }
}
```

- Makefile:

```
all: list
list: list.c
    gcc -Wall -g -o list list.c
clean:
    rm -fr list list.o *~
```