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CS 342 - 002
Homework 1

Question 2: My computer's operating system is macOS Big Sur version 11.6. First of all, I installed Oracle's VirtualBox to be able to use Linux operating system on my computer. Then, I installed Ubuntu 64-bit 20.04 LTS. While installing both Virtual Box and Ubuntu, I watched various Youtube videos and they helped me a lot.

I learned the following 10 Linux commands after setting everything up:

- sudo: It is the abbreviation of "SuperUser Do". It gives permissions to any other command that the user wants to execute.
- touch: It is used to create, change, and modify the timestamps of a file.
- cd: It is also known as "chdir". It changes the current working directory.
- ls: It is used to list files.
- mkdir: It is used to create new directories.
- pwd: It is the abbreviation of "Print Working Directory". It is used to display the full path of a directory.
- cat: It is used to read and output the contents of a file.
- cp: It is the abbreviation of "Copy". It is used to copy files.
- rm: It is the abbreviation of "Remove Here". It is used to remove the entires of a file.
- mv: It is used to move files from one directory to another or rename a file.

Question 3: The name of the kernel executable is vmlinuz and it resides under the /boot directory. The version of the running kernel is 5.13.0-28-generic.

```
melisatun@melisatun-VirtualBox:~/Desktop$ cd /boot
melisatun@melisatun-VirtualBox:/boot$ ls
config-5.11.0-27-generic      memtest86+.elf
config-5.13.0-28-generic      memtest86+_multiboot.bin
efi                           System.map-5.11.0-27-generic
grub                          System.map-5.13.0-28-generic
initrd.img                    vmlinuz
initrd.img-5.11.0-27-generic  vmlinuz-5.11.0-27-generic
initrd.img-5.13.0-28-generic  vmlinuz-5.13.0-28-generic
initrd.img.old                vmlinuz.old
memtest86+.bin
melisatun@melisatun-VirtualBox:/boot$
```

Question 4: Kernel 5.15.22 version is downloaded. Subdirectories are the following:

- arch
- block
- certs
- crypto
- Documentation
- drivers
- fs
- include
- init
- ipc
- kernel
- lib
- LICENSES
- mm
- net
- samples

- scripts
- security
- sound
- tools
- usr
- virt

Question 5: System call table's path is:

/linux-5.12.22.tar.xz\linux-5.12.22\arch\x86\entry\syscalls\syscalls_64.tbl

★ 3 - close

★ 35 - nanosleep

★ 110 - getppid

★ 210 - io_cancel

Question 6: The output of *strace ls* command is:

```
melisatun@melisatun-VirtualBox:/boot$ strace ls
execve("/usr/bin/ls", ["ls"], 0x7ffedc3489f0 /* 58 vars */) = 0
brk(NULL)                               = 0x5555a3e64000
arch_prctl(0x3001 /* ARCH_??? */, 0x7ffec9b000d0) = -1 EINVAL (Invalid argument
)
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
fstat(3, {st_mode=S_IFREG|0644, st_size=64658, ...}) = 0
mmap(NULL, 64658, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7f750b10d000
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@p\0\0\0\0\0\0"..., 832)
 = 832
fstat(3, {st_mode=S_IFREG|0644, st_size=163200, ...}) = 0
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7f
750b10b000
mmap(NULL, 174600, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f750b0e0000
mprotect(0x7f750b0e6000, 135168, PROT_NONE) = 0
mmap(0x7f750b0e6000, 102400, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|MAP_DEN
YWRITE, 3, 0x6000) = 0x7f750b0e6000
mmap(0x7f750b0ff000, 28672, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x1f000) = 0x7f750b0ff000
mmap(0x7f750b107000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENY
WRITE, 3, 0x26000) = 0x7f750b107000
mmap(0x7f750b109000, 6664, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANON
YMOUS, -1, 0) = 0x7f750b109000
```

```
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\340\"\0\0\0\0\0\0"..., 8
832) = 832
fstat(3, {st_mode=S_IFREG|0644, st_size=584392, ...}) = 0
mmap(NULL, 586536, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f750ae5e000
mmap(0x7f750ae60000, 409600, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|MAP_DEN
YWRITE, 3, 0x2000) = 0x7f750ae60000
mmap(0x7f750aec4000, 163840, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
 0x66000) = 0x7f750aec4000
mmap(0x7f750aeec000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENY
WRITE, 3, 0x8d000) = 0x7f750aeec000
close(3)                                = 0
openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libdl.so.2", 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 \22\0\0\0\0\0\0"..., 83
2) = 832
fstat(3, {st_mode=S_IFREG|0644, st_size=18816, ...}) = 0
mmap(NULL, 20752, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f750ae58000
mmap(0x7f750ae59000, 8192, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|MAP_DENYW
RITE, 3, 0x1000) = 0x7f750ae59000
mmap(0x7f750ae5b000, 4096, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0
x3000) = 0x7f750ae5b000
mmap(0x7f750ae5c000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENY
WRITE, 3, 0x3000) = 0x7f750ae5c000
close(3)                                = 0
openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libpthread.so.0", O_RDONLY|O_CLOEXEC) =
 3
```

```
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\0\360q\2\0\0\0\0\0"..., 8
32) = 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\20\0\0\0\5\0\0\0GNU\0\2\0\0\300\4\0\0\0\3\0\0\0\0\0\0\0",
32, 848) = 32
pread64(3, "\4\0\0\0\24\0\0\0\3\0\0\0GNU\0\t\233\222%\274\260\320\31\331\326\10
\204\276X>\263"..., 68, 880) = 68
fstat(3, {st_mode=S_IFREG|0755, st_size=2029224, ...}) = 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
pread64(3, "\4\0\0\0\20\0\0\0\5\0\0\0GNU\0\2\0\0\300\4\0\0\0\3\0\0\0\0\0\0\0",
32, 848) = 32
pread64(3, "\4\0\0\0\24\0\0\0\3\0\0\0GNU\0\t\233\222%\274\260\320\31\331\326\10
\204\276X>\263"..., 68, 880) = 68
mmap(NULL, 2036952, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f750aeee00
0
mprotect(0x7f750af13000, 1847296, PROT_NONE) = 0
mmap(0x7f750af13000, 1540096, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|MAP_DE
NYWRITE, 3, 0x25000) = 0x7f750af13000
mmap(0x7f750b08b000, 303104, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
 0x19d000) = 0x7f750b08b000
mmap(0x7f750b0d6000, 24576, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DEN
YWRITE, 3, 0x1e7000) = 0x7f750b0d6000
mmap(0x7f750b0dc000, 13528, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANO
NYMOUS, -1, 0) = 0x7f750b0dc000
```

```
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\220\201\0\0\0\0\0\0"...
, 832) = 832
pread64(3, "\4\0\0\0\24\0\0\0\3\0\0\0GNU\0\345Ga\367\265T\320\374\301V)Yf]\223\
337"..., 68, 824) = 68
fstat(3, {st_mode=S_IFREG|0755, st_size=157224, ...}) = 0
pread64(3, "\4\0\0\0\24\0\0\0\3\0\0\0GNU\0\345Ga\367\265T\320\374\301V)Yf]\223\
337"..., 68, 824) = 68
mmap(NULL, 140408, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f750ae35000
mmap(0x7f750ae3c000, 69632, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|MAP_DENY
WRITE, 3, 0x7000) = 0x7f750ae3c000
mmap(0x7f750ae4d000, 20480, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x18000) = 0x7f750ae4d000
mmap(0x7f750ae52000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENY
WRITE, 3, 0x1c000) = 0x7f750ae52000
mmap(0x7f750ae54000, 13432, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANO
NYMOUS, -1, 0) = 0x7f750ae54000
close(3)                                = 0
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7f
750ae33000
arch_prctl(ARCH_SET_FS, 0x7f750ae34400) = 0
mprotect(0x7f750b0d6000, 12288, PROT_READ) = 0
mprotect(0x7f750ae52000, 4096, PROT_READ) = 0
mprotect(0x7f750ae5c000, 4096, PROT_READ) = 0
mprotect(0x7f750aeec000, 4096, PROT_READ) = 0
mprotect(0x7f750b107000, 4096, PROT_READ) = 0
mprotect(0x5555a3cdf000, 4096, PROT_READ) = 0
mprotect(0x7f750b14a000, 4096, PROT_READ) = 0
munmap(0x7f750b10d000, 64658)           = 0
```

```
set_tid_address(0x7f750ae346d0)         = 34621
set_robust_list(0x7f750ae346e0, 24)     = 0
rt_sigaction(SIGRTMIN, {sa_handler=0x7f750ae3cbf0, sa_mask=[], sa_flags=SA_REST
ORER|SA_SIGINFO, sa_restorer=0x7f750ae4a3c0}, NULL, 8) = 0
rt_sigaction(SIGRT_1, {sa_handler=0x7f750ae3cc90, sa_mask=[], sa_flags=SA_RESTO
RER|SA_RESTART|SA_SIGINFO, sa_restorer=0x7f750ae4a3c0}, NULL, 8) = 0
rt_sigprocmask(SIG_UNBLOCK, [RTMIN RT_1], NULL, 8) = 0
prlimit64(0, RLIMIT_STACK, NULL, {rlim_cur=8192*1024, rlim_max=RLIM64_INFINITY}
) = 0
statfs("/sys/fs/selinux", 0x7ffec9b00020) = -1 ENOENT (No such file or director
y)
statfs("/selinux", 0x7ffec9b00020)      = -1 ENOENT (No such file or directory)
brk(NULL)                               = 0x5555a3e64000
brk(0x5555a3e85000)                     = 0x5555a3e85000
openat(AT_FDCWD, "/proc/filesystems", O_RDONLY|O_CLOEXEC) = 3
fstat(3, {st_mode=S_IFREG|0444, st_size=0, ...}) = 0
read(3, "nodev\tsysfs\nnodev\ttmpfs\nnodev\tbd"..., 1024) = 369
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
fstat(3, {st_mode=S_IFREG|0644, st_size=17339232, ...}) = 0
mmap(NULL, 17339232, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7f7509da9000
close(3)                                = 0
ioctl(1, TCGETS, {B38400 opost isig icanon echo ...}) = 0
ioctl(1, TIOCGWINSZ, {ws_row=29, ws_col=79, ws_xpixel=0, ws_ypixel=0}) = 0
openat(AT_FDCWD, ".", O_RDONLY|O_NONBLOCK|O_CLOEXEC|O_DIRECTORY) = 3
```

```
fstat(3, {st_mode=S_IFDIR|0755, st_size=4096, ...}) = 0
getdents64(3, /* 19 entries */, 32768)  = 744
getdents64(3, /* 0 entries */, 32768)   = 0
close(3)                                = 0
fstat(1, {st_mode=S_IFCHR|0620, st_rdev=makedev(0x88, 0x1), ...}) = 0
write(1, "config-5.11.0-27-generic      me"..., 45config-5.11.0-27-generic
 memtest86+.elf
) = 45
write(1, "config-5.13.0-28-generic      me"..., 55config-5.13.0-28-generic
 memtest86+_multiboot.bin
) = 55
write(1, "efi\t\t\t      System.map-5.11.0-27"..., 41efi
     System.map-5.11.0-27-generic
) = 41
write(1, "grub\t\t\t      System.map-5.13.0-2"..., 42grub
     System.map-5.13.0-28-generic
) = 42
write(1, "initrd.img\t\t      vmlinuz\n", 26initrd.img                vmlinuz
) = 26
write(1, "initrd.img-5.11.0-27-generic  vm"..., 56initrd.img-5.11.0-27-generic
 vmlinuz-5.11.0-27-generic
) = 56
write(1, "initrd.img-5.13.0-28-generic  vm"..., 56initrd.img-5.13.0-28-generic
 vmlinuz-5.13.0-28-generic
) = 56
write(1, "initrd.img.old\t\t      vmlinuz.ol"..., 34initrd.img.old
```

```
) = 45
write(1, "config-5.13.0-28-generic      me"..., 55config-5.13.0-28-generic
 memtest86+_multiboot.bin
) = 55
write(1, "efi\t\t\t      System.map-5.11.0-27"..., 41efi
     System.map-5.11.0-27-generic
) = 41
write(1, "grub\t\t\t      System.map-5.13.0-2"..., 42grub
     System.map-5.13.0-28-generic
) = 42
write(1, "initrd.img\t\t      vmlinuz\n", 26initrd.img                vmlinuz
) = 26
write(1, "initrd.img-5.11.0-27-generic  vm"..., 56initrd.img-5.11.0-27-generic
 vmlinuz-5.11.0-27-generic
) = 56
write(1, "initrd.img-5.13.0-28-generic  vm"..., 56initrd.img-5.13.0-28-generic
 vmlinuz-5.13.0-28-generic
) = 56
write(1, "initrd.img.old\t\t      vmlinuz.ol"..., 34initrd.img.old
     vmlinuz.old
) = 34
write(1, "memtest86+.bin\n", 15memtest86+.bin
)       = 15
close(1)                                = 0
close(2)                                = 0
exit_group(0)                           = ?
+++ exited with 0 +++
```

Question 7:

- ➢ real: The total time elapsed to execute a program from the start to the end of the call.
- ➢ user: The amount of CPU time spent in user-mode outside the kernel.
- ➢ sys: The amount of CPU time spent inside the kernel.

commands	real	user	sys
time strace ls	0.042s	0.004s	0.014s
time cp files	0.002s	0.002s	0.000s
time cp Rhythmbox	0.002s	0.002s	0.002s
time sudo	0.013s	0.005s	0.000s

Question 8:

- **time elapsed for inserting 10000 random integers into a linked list: 495 microseconds**

sample code (list.c)

```
#include <stdio.h>
#include <stdlib.h>
#include <sys/time.h>
struct Node {
    int data;
    struct Node* next;
};
void insert(struct Node** head, int newData) {
    struct Node* node = (struct Node*) malloc(sizeof(struct Node));
    node->data = newData;
    node->next = (*head);
    (*head) = node;
}
void printList(struct Node* node) {
```

```
while (node != NULL) {
     printf(“ %d ”, node->data);
     node = node->next;
}
}
int main() {
    struct timeval start;
    struct timeval end;
    gettimeofday(&start, NULL);
    struct Node* head = NULL;
    int data;
    for (int i = 0; i < 10000; i++) {
        data = rand() % 10000;
        insert(&head, data);
    }
    gettimeofday(&end, NULL);
    printf(“Time taken for inserting 10000 integers is: %ld ”, end.tv_usec-start.tv_usec);
    return 0;
}
```

Makefile:

```
all: list

list: list.c
	gcc -Wall -g -o list list.c

clean:
	rm -fr list list.o *~
```

Output of the sample code with the Makefile above: