1. My computer uses the macOS Big Sur version 11.1 as the Operating System. I decided to install Oracle's VM VirtualBox 6.1 instead of installing the Ubuntu Desktop 64-bit 20.04 LTS directly to my hardware which requires allocating partition of my hard-disk space. The VirtualBox has continuous release cycles and maintained by Oracle so it can be considered as a reliable product. I followed YouTube tutorials throughout the installation process and setting up Ubuntu Desktop 64-bit 20.04 LTS on my MacBook via VirtualBox.

   10 Linux commands I learnt:

   - `touch`: Create a new file.
   - `sudo`: Allow users to run programs with security privileges of the superuser or root .
   - `cd`: Change a particular directory
   - `man`: Get help information about a command.
   - `clear`: Clear the terminal screen.
   - `apt-get`: Install and update a packages.
   - `ls`: List all directories and files in the current working directory.
   - `history`: Shows the list of all commands used in the current terminal session.
   - `rmdir`: Command to remove a particular directory.
   - `mkdir`: Create a new directory.

2. (a) `vmlinuz` is the kernel executable which can be found under the `/boot` directory.
   (b) Version of the kernel: `5.8.0-41-generic`.

3. I downloaded the version `5.10.12` from `kernel.org`, it was the closest version to my kernel.

   The sub-directories under the root directory `/linux-5.10.12/` are as follows:

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

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4. The pathname of **the system call table**: /linux-5.10.12/arch/x86/entry/syscalls/syscall_64.tbl.

   The system call names mapping to the given system call numbers:

   - 3: close
   - 35: nanosleep
   - 110: getppid
   - 210: io_cancel

5. The strace command tracks the system call names together with it's arguments and return value until it exits from command.

   Output of example strace ls command

```
zcankara@zcankara-VirtualBox:~$ strace ls
execve("/usr/bin/ls", ["ls"], 0x7ffe23913290 /* 61 vars */) = 0
brk(NULL)                               = 0x56244775e000
arch_prctl(0x3001 /* ARCH_??? */, 0x7fff2d2cf470) = -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=66821, ...}) = 0
mmap(NULL, 66821, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7f19e576b000
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\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) = 0x7f19e5769000
mmap(NULL, 174600, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f19e573e000
mprotect(0x7f19e5744000, 135168, PROT_NONE) = 0
mmap(0x7f19e5744000, 102400, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
↪  0x6000) = 0x7f19e5744000
mmap(0x7f19e575d000, 28672, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x1f000) =
↪  0x7f19e575d000
mmap(0x7f19e5765000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
↪  0x26000) = 0x7f19e5765000
mmap(0x7f19e5767000, 6664, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0)
↪  = 0x7f19e5767000
close(3)                                = 0
```

```
21 openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libc.so.6", O_RDONLY|O_CLOEXEC) = 3
22 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"..., 832) = 832
23 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
24 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
25 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
26 fstat(3, {st_mode=S_IFREG|0755, st_size=2029224, ...}) = 0
27 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
28 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
29 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
30 mmap(NULL, 2036952, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f19e554c000
31 mprotect(0x7f19e5571000, 1847296, PROT_NONE) = 0
32 mmap(0x7f19e5571000, 1540096, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
   ↪ 0x25000) = 0x7f19e5571000
33 mmap(0x7f19e56e9000, 303104, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x19d000) =
   ↪ 0x7f19e56e9000
34 mmap(0x7f19e5734000, 24576, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
   ↪ 0x1e7000) = 0x7f19e5734000
35 mmap(0x7f19e573a000, 13528, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1,
   ↪ 0) = 0x7f19e573a000
36 close(3)                                = 0
37 openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libpcre2-8.so.0", O_RDONLY|O_CLOEXEC) = 3
38 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"..., 832) = 832
39 fstat(3, {st_mode=S_IFREG|0644, st_size=584392, ...}) = 0
40 mmap(NULL, 586536, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f19e54bc000
41 mmap(0x7f19e54be000, 409600, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
   ↪ 0x2000) = 0x7f19e54be000
42 mmap(0x7f19e5522000, 163840, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x66000) =
   ↪ 0x7f19e5522000
43 mmap(0x7f19e554a000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
   ↪ 0x8d000) = 0x7f19e554a000
44 close(3)                                = 0
45 openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libdl.so.2", O_RDONLY|O_CLOEXEC) = 3
46 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"..., 832) = 832
47 fstat(3, {st_mode=S_IFREG|0644, st_size=18816, ...}) = 0
48 mmap(NULL, 20752, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f19e54b6000
49 mmap(0x7f19e54b7000, 8192, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
   ↪ 0x1000) = 0x7f19e54b7000
50 mmap(0x7f19e54b9000, 4096, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x3000) =
   ↪ 0x7f19e54b9000
51 mmap(0x7f19e54ba000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
   ↪ 0x3000) = 0x7f19e54ba000
52 close(3)                                = 0
```

```
openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libpthread.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\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) = 0x7f19e5493000
mmap(0x7f19e549a000, 69632, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x7000) = 0x7f19e549a000
mmap(0x7f19e54ab000, 20480, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x18000) = 0x7f19e54ab000
mmap(0x7f19e54b0000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x1c000) = 0x7f19e54b0000
mmap(0x7f19e54b2000, 13432, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0x7f19e54b2000
close(3)                                = 0
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7f19e5491000
arch_prctl(ARCH_SET_FS, 0x7f19e5492400) = 0
mprotect(0x7f19e5734000, 12288, PROT_READ) = 0
mprotect(0x7f19e54b0000, 4096, PROT_READ) = 0
mprotect(0x7f19e54ba000, 4096, PROT_READ) = 0
mprotect(0x7f19e554a000, 4096, PROT_READ) = 0
mprotect(0x7f19e5765000, 4096, PROT_READ) = 0
mprotect(0x562446328000, 4096, PROT_READ) = 0
mprotect(0x7f19e57a9000, 4096, PROT_READ) = 0
munmap(0x7f19e576b000, 66821)           = 0
set_tid_address(0x7f19e54926d0)         = 3223
set_robust_list(0x7f19e54926e0, 24)     = 0
rt_sigaction(SIGRTMIN, {sa_handler=0x7f19e549abf0, sa_mask=[], sa_flags=SA_RESTORER|SA_SIGINFO, sa_restorer=0x7f19e54a83c0}, NULL, 8) = 0
rt_sigaction(SIGRT_1, {sa_handler=0x7f19e549ac90, sa_mask=[], sa_flags=SA_RESTORER|SA_RESTART|SA_SIGINFO, sa_restorer=0x7f19e54a83c0}, 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", 0x7fff2d2cf3c0) = -1 ENOENT (No such file or directory)
statfs("/selinux", 0x7fff2d2cf3c0)      = -1 ENOENT (No such file or directory)
brk(NULL)                               = 0x56244775e000
brk(0x56244777f000)                     = 0x56244777f000
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) = 387
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=8500896, ...}) = 0
mmap(NULL, 8500896, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7f19e4c75000
```

```
close(3)                                = 0
ioctl(1, TCGETS, {B38400 opost isig icanon echo ...}) = 0
ioctl(1, TIOCGWINSZ, {ws_row=24, ws_col=80, 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, /* 26 entries */, 32768)  = 912
getdents64(3, /* 0 entries */, 32768)   = 0
close(3)                                = 0
fstat(1, {st_mode=S_IFCHR|0620, st_rdev=makedev(0x88, 0x1), ...}) = 0
write(1, "Desktop    Downloads\t  Music    "..., 51Desktop    Downloads          Music
↪  Public     Videos
) = 51
write(1, "Documents  linux-5.10.12  Pictur"..., 46Documents  linux-5.10.12  Pictures
↪  Templates
) = 46
close(1)                                = 0
close(2)                                = 0
exit_group(0)                           = ?
+++ exited with 0 +++
```

6. The `time` command measures the execution time of a process and provides various statistics.

   - `sys:` The CPU time spent in Kernel mode where privalaged instructions can be executed.
   - `user:` The CPU time spent in User mode where privalaged instructions cannot be executed.
   - `real:` The total time elapsed to execute the program.

Time statistics of various programs			
Command	sys	user	real
strace ls	0.002s	0.006s	0.019s
time cp Music	0.000s	0.001s	0.002s
touch new.txt	0.000s	0.001s	0.004s
time strace mkdir new	0.002s	0.004s	0.010s

7. Sample code for linked list implementation C. Inserting random 1000 numbers and measures the time it takes via `gettimeofday()` system call.

   Time taken to populate linked list with 10000 random numbers : `639 micro seconds`

   list.c

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

struct node {
   int data;
   struct node *next;
};

void insert(struct node ** head, int data) {
  struct node *node= (struct node*) malloc(sizeof(struct node));
  node->data = data;
  node->next = *head;
  *head = node;
}

int main() {
  struct timeval start, end;
  gettimeofday(&start, NULL);
  // insert 10000 random numbers to the linked list
  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 to count to populate linked list with 10000 random numbers : %ld micro
  ↪  seconds\n",
    ((end.tv_sec * 1000000 + end.tv_usec) -
    (start.tv_sec * 1000000 + start.tv_usec)));
  return 0;
}
```

Makefile

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