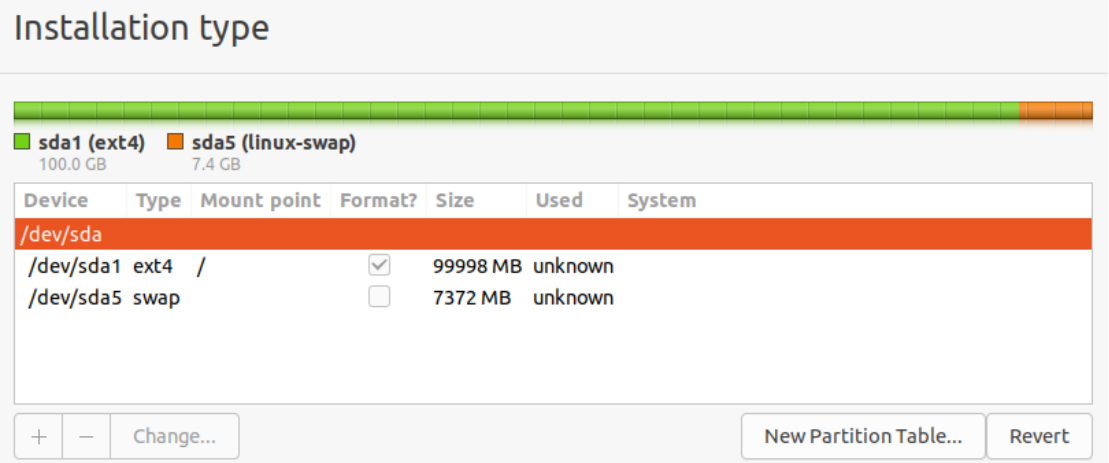
Operating Systems Project Report

Project Number (01 / 02 / 03):	02
Name:	呂芯瑄
Student ID:	0816057
YouTube link (Format youtube.com/watch?v=[key]):	https://youtu.be/XUkJSVe5OQY
Date (YYYY-MM-DD):	2021/11/26
Names of the files uploaded to E3:	OS_Project02_0816057.pdf, K4_numericalTest.c, K5_numericalTest.c, K4_syscall_64.tbl, K5_syscall_64.tbl, K4_syscalls.h, K5_syscalls.h, syscallsNumerical.c
Physical Machine Total RAM (Example: 8.0 GB):	24.0GB
Physical Machine CPU (Example: Intel i7-2600K):	Intel i5-11400F

Checklist	
Yes/No	**Item**
y	**The report name follows the format "OS_ProjectXX_StudentID.pdf".**
y	**The report was uploaded to E3 before the deadline.**
y	**The YouTube video is public, and anyone with the link can watch it.**
y	**The audio of the video has a good volume.**
y	**The pictures in your report and video have a good quality.**
y	**All the questions and exercises were answered inside the report.**
y	**I understand that late submission is late submission, regardless of the time uploaded.**
y	**I understand that any cheating in my report / video / code will not be tolerated.**

Screenshot #1




```
usertest0816057@usertest0816057-virtual-machine:/usr/src$ ls
linux-4.19.148  linux-4.19.148.tar  linux-5.13.19  linux-5.13.19.tar  linux-hea
ders-5.11.0-27-generic  linux-headers-5.11.0-40-generic  linux-hwe-5.11-headers
-5.11.0-27  linux-hwe-5.11-headers-5.11.0-40
```

```
usertest0816057@usertest0816057-virtual-machine:/usr/src/linux-4.19.148$ ls
arch    certs     CREDITS  Documentation  firmware  include  ipc     Kconfig  lib
        MAINTAINERS  mm    README   scripts   sound  usr
block   COPYING  crypto   drivers        fs        init     Kbuild  kernel   LIC
ENSES   Makefile     net  samples  security  tools  virt
```

```
usertest0816057@usertest0816057-virtual-machine:/usr/src/linux-5.13.19$ ls
arch    certs     CREDITS  Documentation  fs        init  Kbuild   kernel  LICENSE
S     Makefile  net     samples  security  tools  virt
block   COPYING  crypto   drivers        include  ipc   Kconfig  lib     MAINTAI
NERS  mm        README   scripts  sound     usr
```

Screenshot #2

```
usertest0816057@usertest0816057-virtual-machine:/usr/src/linux-4.19.148$ ls -a
.     block          .cocciconfig  CREDITS        drivers   .get_maintainer.ign
ore  include  Kbuild   lib        MAINTAINERS  net      scripts   tools
..    certs          .config       crypto         firmware  .gitattributes
     init     Kconfig  LICENSES  Makefile     README   security  usr
arch  .clang-format  COPYING       Documentation  fs        .gitignore
     ipc      kernel   .mailmap  mm           samples  sound     virt
```

```
usertest0816057@usertest0816057-virtual-machine:/usr/src/linux-5.13.19$ ls -a
.   arch   certs          .cocciconfig  COPYING  crypto         drivers  .get_m
aintainer.ignore  .gitignore  init  Kbuild   kernel  LICENSES  MAINTAINERS  mm
  README   scripts   sound  usr
..  block  .clang-format  .config       CREDITS  Documentation  fs       .gitat
tributes          include     ipc   Kconfig  lib     .mailmap  Makefile     net
  samples  security  tools  virt
```

Screenshot #03

```
usertest0816057@usertest0816057-virtual-machine:/usr/src/linux-4.19.148$ sudo make -j $(nproc)
  HOSTCC  scripts/basic/fixdep
  HOSTCC  scripts/kconfig/conf.o
  YACC    scripts/kconfig/zconf.tab.c
  LEX     scripts/kconfig/zconf.lex.c
  HOSTCC  scripts/kconfig/zconf.tab.o
  HOSTLD  scripts/kconfig/conf
scripts/kconfig/conf  --syncconfig Kconfig
```

```
usertest0816057@usertest0816057-virtual-machine:/usr/src/linux-5.13.19$ sudo make -j $(nproc)
  SYNC    include/config/auto.conf.cmd
  HOSTCC  scripts/basic/fixdep
  HOSTCC  scripts/kconfig/conf.o
  HOSTCC  scripts/kconfig/confdata.o
  HOSTCC  scripts/kconfig/expr.o
  LEX     scripts/kconfig/lexer.lex.c
  YACC    scripts/kconfig/parser.tab.[ch]
  HOSTCC  scripts/kconfig/menu.o
  HOSTCC  scripts/kconfig/parser.tab.o
  HOSTCC  scripts/kconfig/preprocess.o
  HOSTCC  scripts/kconfig/symbol.o
  HOSTCC  scripts/kconfig/util.o
  HOSTCC  scripts/kconfig/lexer.lex.o
```

Screenshot #4

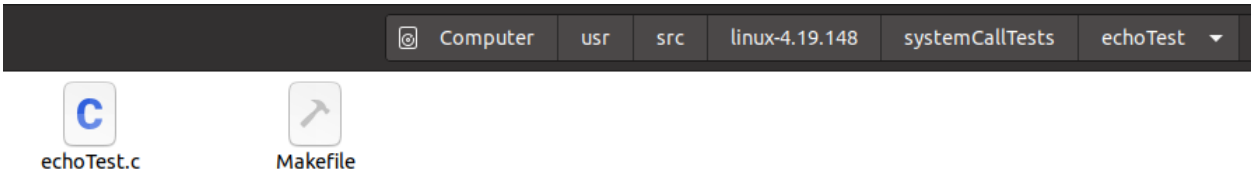
```
usertest0816057@usertest0816057-virtual-machine:~$ sudo nano /etc/default/grub
[sudo] password for usertest0816057:
usertest0816057@usertest0816057-virtual-machine:~$ sudo update-grub
Sourcing file `/etc/default/grub'
Sourcing file `/etc/default/grub.d/init-select.cfg'
Generating grub configuration file ...
Found linux image: /boot/vmlinuz-5.13.19
Found initrd image: /boot/initrd.img-5.13.19
Found linux image: /boot/vmlinuz-5.11.0-40-generic
Found initrd image: /boot/initrd.img-5.11.0-40-generic
Found linux image: /boot/vmlinuz-5.11.0-27-generic
Found initrd image: /boot/initrd.img-5.11.0-27-generic
Found linux image: /boot/vmlinuz-4.19.148
Found initrd image: /boot/initrd.img-4.19.148
Found memtest86+ image: /boot/memtest86+.elf
Found memtest86+ image: /boot/memtest86+.bin
done
```

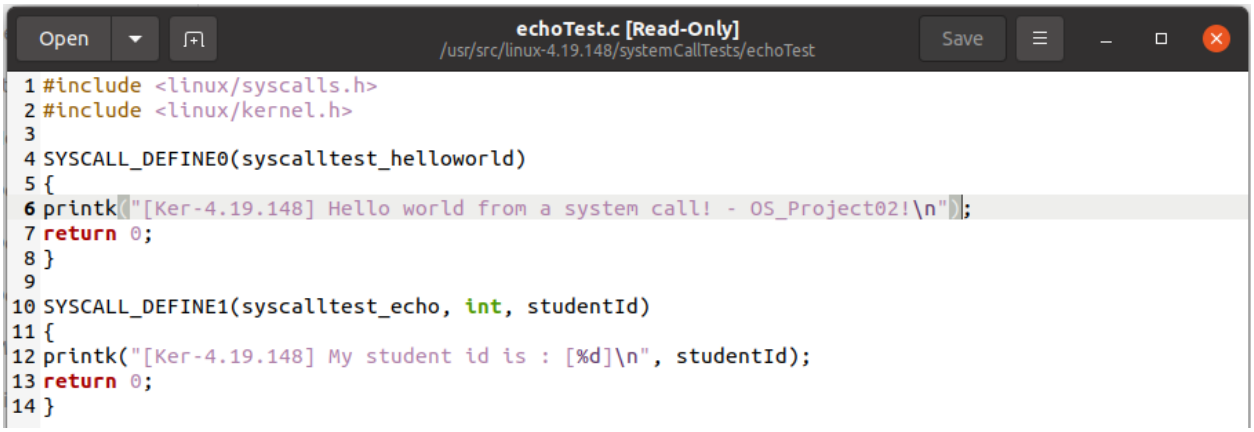
```
                    GNU GRUB  version 2.04

 *Ubuntu, with Linux 5.13.19
  Ubuntu, with Linux 5.13.19 (recovery mode)
  Ubuntu, with Linux 5.11.0-40-generic
  Ubuntu, with Linux 5.11.0-40-generic (recovery mode)
  Ubuntu, with Linux 5.11.0-27-generic
  Ubuntu, with Linux 5.11.0-27-generic (recovery mode)
  Ubuntu, with Linux 4.19.148
  Ubuntu, with Linux 4.19.148 (recovery mode)
```

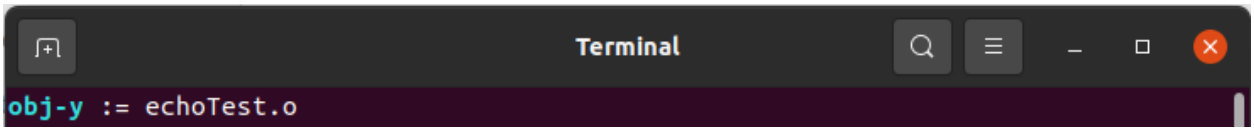
Screenshot #5

```
usertest0816057@usertest0816057-virtual-machine:~/Desktop$ uname -r
4.19.148

usertest0816057@usertest0816057-virtual-machine:~/Desktop$ uname -r
5.13.19
```

Screenshot #6







Screenshot #7

```
540     x32     process_vm_writev       __x32_compat_sys_process_vm_writev
541     x32     setsockopt              __x32_compat_sys_setsockopt
542     x32     getsockopt              __x32_compat_sys_getsockopt
543     x32     io_setup                __x32_compat_sys_io_setup
544     x32     io_submit               __x32_compat_sys_io_submit
545     x32     execveat                __x32_compat_sys_execveat/ptregs
546     x32     preadv2                 __x32_compat_sys_preadv64v2
547     x32     pwritev2                __x32_compat_sys_pwritev64v2
```

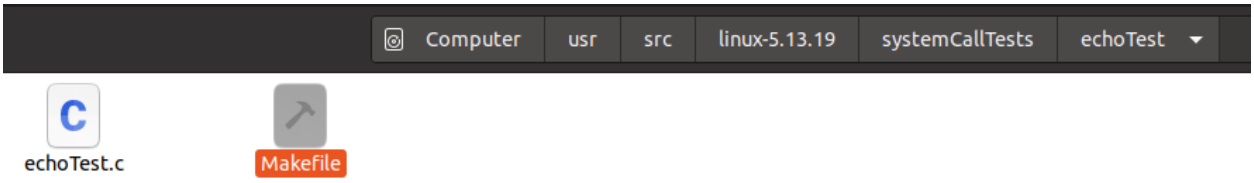
Screenshot #8

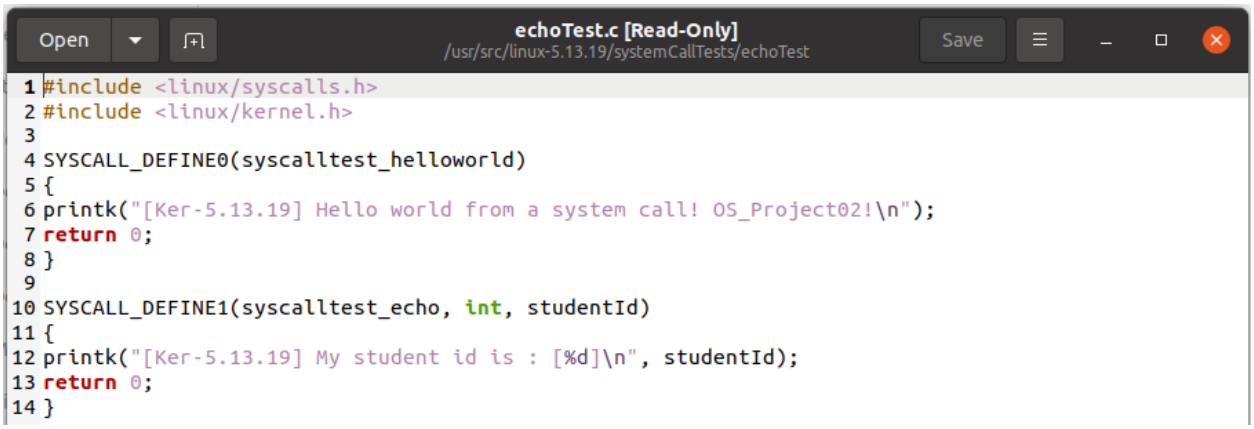
```
540     x32     process_vm_writev       __x32_compat_sys_process_vm_writev
541     x32     setsockopt              __x32_compat_sys_setsockopt
542     x32     getsockopt              __x32_compat_sys_getsockopt
543     x32     io_setup                __x32_compat_sys_io_setup
544     x32     io_submit               __x32_compat_sys_io_submit
545     x32     execveat                __x32_compat_sys_execveat/ptregs
546     x32     preadv2                 __x32_compat_sys_preadv64v2
547     x32     pwritev2                __x32_compat_sys_pwritev64v2
548     common  syscalltest_helloworld  __x64_sys_syscalltest_helloworld
549     common  syscalltest_echo        __x64_sys_syscalltest_echo
```

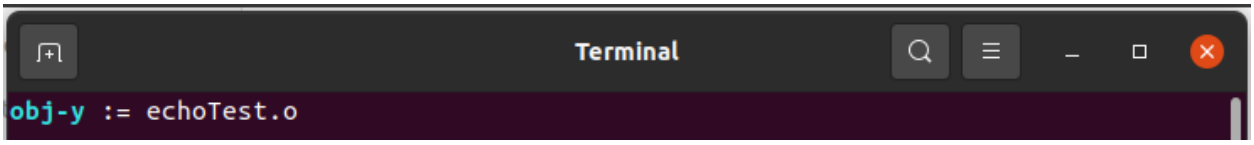
Screenshot #9

```
static inline unsigned int ksys_personality(unsigned int personality)
{
        unsigned int old = current->personality;

        if (personality != 0xffffffff)
                set_personality(personality);

        return old;
}
asmlinkage long syscalltest_helloworld(void);
asmlinkage long syscalltest_echo(int);

#endif
```

Screenshot #10







Screenshot #11

```
543     x32     io_setup                compat_sys_io_setup
544     x32     io_submit               compat_sys_io_submit
545     x32     execveat                compat_sys_execveat
546     x32     preadv2                 compat_sys_preadv64v2
547     x32     pwritev2                compat_sys_pwritev64v2
# This is the end of the legacy x32 range.  Numbers 548 and above are
# not special and are not to be used for x32-specific syscalls.
```

Screenshot #12

```
543     x32     io_setup                compat_sys_io_setup
544     x32     io_submit               compat_sys_io_submit
545     x32     execveat                compat_sys_execveat
546     x32     preadv2                 compat_sys_preadv64v2
547     x32     pwritev2                compat_sys_pwritev64v2
# This is the end of the legacy x32 range.  Numbers 548 and above are
# not special and are not to be used for x32-specific syscalls.

554     64      syscalltest_helloworld  sys_syscalltest_helloworld
555     64      syscalltest_echo        sys_syscalltest_echo
```

Screenshot #13

```
int __sys_getsockopt(int fd, int level, int optname, char __user *optval,
                int __user *optlen);
int __sys_setsockopt(int fd, int level, int optname, char __user *optval,
                int optlen);
asmlinkage long syscalltest_helloworld(void);
asmlinkage long syscalltest_echo(int);

#endif
```

Screenshot #14

```
usertest0816057@usertest0816057-virtual-machine:/usr/src/linux-4.19.148$ sudo make install
sh ./arch/x86/boot/install.sh 4.19.148 arch/x86/boot/bzImage \
        System.map "/boot"
run-parts: executing /etc/kernel/postinst.d/apt-auto-removal 4.19.148 /boot/vmlinuz-4.19.148
run-parts: executing /etc/kernel/postinst.d/initramfs-tools 4.19.148 /boot/vmlinuz-4.19.148
update-initramfs: Generating /boot/initrd.img-4.19.148
I: The initramfs will attempt to resume from /dev/sda5
I: (UUID=e55a4a2f-fb90-4a0a-913e-8ff65f7dd177)
I: Set the RESUME variable to override this.
run-parts: executing /etc/kernel/postinst.d/unattended-upgrades 4.19.148 /boot/vmlinuz-4.19.148
run-parts: executing /etc/kernel/postinst.d/update-notifier 4.19.148 /boot/vmlinuz-4.19.148
run-parts: executing /etc/kernel/postinst.d/xx-update-initrd-links 4.19.148 /boot/vmlinuz-4.19.148
I: /boot/vmlinuz.old is now a symlink to vmlinuz-5.13.19
I: /boot/initrd.img.old is now a symlink to initrd.img-5.13.19
I: /boot/vmlinuz is now a symlink to vmlinuz-4.19.148
I: /boot/initrd.img is now a symlink to initrd.img-4.19.148
run-parts: executing /etc/kernel/postinst.d/zz-update-grub 4.19.148 /boot/vmlinuz-4.19.148
Sourcing file `/etc/default/grub'
Sourcing file `/etc/default/grub.d/init-select.cfg'
Generating grub configuration file ...
Found linux image: /boot/vmlinuz-5.13.19
Found initrd image: /boot/initrd.img-5.13.19
Found linux image: /boot/vmlinuz-5.13.19.old
Found initrd image: /boot/initrd.img-5.13.19
Found linux image: /boot/vmlinuz-5.11.0-40-generic
Found initrd image: /boot/initrd.img-5.11.0-40-generic
Found linux image: /boot/vmlinuz-5.11.0-27-generic
Found initrd image: /boot/initrd.img-5.11.0-27-generic
Found linux image: /boot/vmlinuz-4.19.148
Found initrd image: /boot/initrd.img-4.19.148
Found linux image: /boot/vmlinuz-4.19.148.old
Found initrd image: /boot/initrd.img-4.19.148
Found memtest86+ image: /boot/memtest86+.elf
Found memtest86+ image: /boot/memtest86+.bin
done
```

```
usertest0816057@usertest0816057-virtual-machine:/usr/src/linux-5.13.19$ sudo make install
arch/x86/Makefile:148: CONFIG_X86_X32 enabled but no binutils support
sh ./arch/x86/boot/install.sh 5.13.19 arch/x86/boot/bzImage \
        System.map "/boot"
run-parts: executing /etc/kernel/postinst.d/apt-auto-removal 5.13.19 /boot/vmlinuz-5.13.19
run-parts: executing /etc/kernel/postinst.d/initramfs-tools 5.13.19 /boot/vmlinuz-5.13.19
update-initramfs: Generating /boot/initrd.img-5.13.19
I: The initramfs will attempt to resume from /dev/sda5
I: (UUID=e55a4a2f-fb90-4a0a-913e-8ff65f7dd177)
I: Set the RESUME variable to override this.
run-parts: executing /etc/kernel/postinst.d/unattended-upgrades 5.13.19 /boot/vmlinuz-5.13.19
run-parts: executing /etc/kernel/postinst.d/update-notifier 5.13.19 /boot/vmlinuz-5.13.19
run-parts: executing /etc/kernel/postinst.d/xx-update-initrd-links 5.13.19 /boot/vmlinuz-5.13.19
run-parts: executing /etc/kernel/postinst.d/zz-update-grub 5.13.19 /boot/vmlinuz-5.13.19
Sourcing file `/etc/default/grub'
Sourcing file `/etc/default/grub.d/init-select.cfg'
Generating grub configuration file ...
Found linux image: /boot/vmlinuz-5.13.19
Found initrd image: /boot/initrd.img-5.13.19
Found linux image: /boot/vmlinuz-5.13.19.old
Found initrd image: /boot/initrd.img-5.13.19
Found linux image: /boot/vmlinuz-5.11.0-40-generic
Found initrd image: /boot/initrd.img-5.11.0-40-generic
Found linux image: /boot/vmlinuz-5.11.0-27-generic
Found initrd image: /boot/initrd.img-5.11.0-27-generic
Found linux image: /boot/vmlinuz-4.19.148
Found initrd image: /boot/initrd.img-4.19.148
Found linux image: /boot/vmlinuz-4.19.148.old
Found initrd image: /boot/initrd.img-4.19.148
Found memtest86+ image: /boot/memtest86+.elf
Found memtest86+ image: /boot/memtest86+.bin
done
```

Screenshot #15

```
usertest0816057@usertest0816057-virtual-machine:~/Desktop/SystemCallsRunTests/echo$ uname -r
4.19.148
usertest0816057@usertest0816057-virtual-machine:~/Desktop/SystemCallsRunTests/echo$ sudo dmesg --clear
[sudo] password for usertest0816057:
usertest0816057@usertest0816057-virtual-machine:~/Desktop/SystemCallsRunTests/echo$ gcc -o syscallsHelloEco syscallsHelloEco.c
usertest0816057@usertest0816057-virtual-machine:~/Desktop/SystemCallsRunTests/echo$ ./syscallsHelloEco
studentId = [816057]

=== Kernel 4.19.148 ===
helloworld : 0
echo : 0

=== Kernel 5.13.19 ===
helloworld : -1
echo : -1
usertest0816057@usertest0816057-virtual-machine:~/Desktop/SystemCallsRunTests/echo$ dmesg
[  574.496766] [Ker-4.19.148] Hello world from a system call! - OS_Project02!
[  574.496768] [Ker-4.19.148] My student id is : [816057]
```

Screenshot #16

```
usertest0816057@usertest0816057-virtual-machine:~/Desktop/SystemCallsRunTests/echo$ uname -r
5.13.19
usertest0816057@usertest0816057-virtual-machine:~/Desktop/SystemCallsRunTests/echo$ ./syscallsHelloEco
studentId = [816057]

=== Kernel 4.19.148 ===
helloworld : -1
echo : -1

=== Kernel 5.13.19 ===
helloworld : 0
echo : 0
usertest0816057@usertest0816057-virtual-machine:~/Desktop/SystemCallsRunTests/echo$ dmesg
[  136.669046] [Ker-5.13.19] Hello world from a system call! OS_Project02!
[  136.669049] [Ker-5.13.19] My student id is : [816057]
```

Screenshot #17

```c
#include <linux/syscalls.h>
#include <linux/kernel.h>

//STUDENT ID: 0816057

int returnValue(int studentId, int a, int b){
        printk("[%d][Ker-4.19.148] syscalltest_returnIndividualValues : [%d][%d]\n", studentId, a, b);
        return 0;
}

int minimum(int studentId, int a, int b, int c){
        int d = a;
        if(b < d) d = b;
        if(c < d) d = c;
        printk("[%d][Ker-4.19.148] syscalltest_minimum : [%d][%d][%d] - [%d]\n", studentId, a, b, c, d);
        return d;
}

int maximum(int studentId, int a, int b, int c){
        int d = a;
        if(b > d) d = b;
        if(c > d) d = c;
        printk("[%d][Ker-4.19.148] syscalltest_maximum : [%d][%d][%d] - [%d]\n", studentId, a, b, c, d);
        return d;
}

int displayDatatypes(int studentId){
        printk("[%d][Ker-4.19.148] size of unsigned int : [%d] bytes\n", studentId, sizeof(unsigned int));
        printk("[%d][Ker-4.19.148] size of signed int : [%d] bytes\n", studentId, sizeof(signed int));
        printk("[%d][Ker-4.19.148] size of unsigned long : [%d] bytes\n", studentId, sizeof(unsigned long));
        printk("[%d][Ker-4.19.148] size of signed long : [%d] bytes\n", studentId, sizeof(signed long));
        printk("[%d][Ker-4.19.148] size of unsigned long long : [%d] bytes\n", studentId, sizeof(unsigned long long));
        printk("[%d][Ker-4.19.148] size of signed long long : [%d] bytes\n", studentId, sizeof(signed long long));
        printk("[%d][Ker-4.19.148] size of double : [%d] bytes\n", studentId, sizeof(double));
        printk("[%d][Ker-4.19.148] size of char : [%d] bytes\n", studentId, sizeof(char));
        return 0;
}

SYSCALL_DEFINE3(syscalltest_returnIndividualValues, int, studentId, int, a, int, b){
        return returnValue(studentId, a, b);
}


SYSCALL_DEFINE4(syscalltest_minimum, int, studentId, int, a, int, b, int, c){
        return minimum(studentId, a, b, c);
}
```

```c
SYSCALL_DEFINE4(syscalltest_maximum, int, studentId, int, a, int, b, int, c){
        return maximum(studentId, a, b, c);
}

SYSCALL_DEFINE1(syscalltest_dataTypes, int, studentId){
        return displayDatatypes(studentId);
}
```

Screenshot #18

```c
#include <linux/syscalls.h>
#include <linux/kernel.h>

//STUDENT ID: 0816057

int returnValue(int studentId, int a, int b){
        printk("[%d][Ker-5.13.19] syscalltest_returnIndividualValues : [%d][%d]\n", studentId, a, b);
        return 0;
}

int addition(int studentId, int a, int b){
        printk("[%d][Ker-5.13.19] syscalltest_addition : [%d][%d][%d]\n", studentId, a, b, a+b);
        return a+b;
}

int multiplication(int studentId, int a, int b){
        printk("[%d][Ker-5.13.19] syscalltest_multiplication : [%d][%d][%d]\n", studentId, a, b, a*b);
        return a*b;
}

int displayDatatypes(int studentId){
        printk("[%d][Ker-5.13.19] size of unsigned int : [%d] bytes\n", studentId, sizeof(unsigned int));
        printk("[%d][Ker-5.13.19] size of signed int : [%d] bytes\n", studentId, sizeof(signed int));
        printk("[%d][Ker-5.13.19] size of unsigned long : [%d] bytes\n", studentId, sizeof(unsigned long));
        printk("[%d][Ker-5.13.19] size of signed long : [%d] bytes\n", studentId, sizeof(signed long));
        printk("[%d][Ker-5.13.19] size of unsigned long long : [%d] bytes\n", studentId, sizeof(unsigned long long));
        printk("[%d][Ker-5.13.19] size of signed long long : [%d] bytes\n", studentId, sizeof(signed long long));
        printk("[%d][Ker-5.13.19] size of double : [%d] bytes\n", studentId, sizeof(double));
        printk("[%d][Ker-5.13.19] size of char : [%d] bytes\n", studentId, sizeof(char));
        return 0;
}

SYSCALL_DEFINE3(syscalltest_returnIndividualValues, int, studentId, int, a, int, b){
        return returnValue(studentId, a, b);
}


SYSCALL_DEFINE3(syscalltest_addition, int, studentId, int, a, int, b){
        return addition(studentId, a, b);
}

SYSCALL_DEFINE3(syscalltest_multiplication, int, studentId, int, a, int, b){
        return multiplication(studentId, a, b);
}

SYSCALL_DEFINE1(syscalltest_dataTypes, int, studentId){
        return displayDatatypes(studentId);
}
```

Screenshot #19

```
ifeq ($(KBUILD_EXTMOD),)
core-y          += kernel/ certs/ mm/ fs/ ipc/ security/ crypto/ block/ systemCallTests/echoTest/ systemCallTests/numericalTest/
```

```
usertest0816057@usertest0816057-virtual-machine:/usr/src/linux-4.19.148/systemCallTests/numericalTest$ sudo bash -c "cat > Makefile"
obj-y := numericalTest.o
```

Screenshot #20

```
545     x32     execveat                __x32_compat_sys_execveat/ptregs
546     x32     preadv2                 __x32_compat_sys_preadv64v2
547     x32     pwritev2                __x32_compat_sys_pwritev64v2
548     common  syscalltest_helloworld  __x64_sys_syscalltest_helloworld
549     common  syscalltest_echo        __x64_sys_syscalltest_echo
550     common  syscalltest_returnIndividualValues      __x64_sys_syscalltest_returnIndividualValues
551     common  syscalltest_minimum     __x64_sys_syscalltest_minimum
552     common  syscalltest_maximum     __x64_sys_syscalltest_maximum
553     common  syscalltest_dataTypes   __x64_sys_syscalltest_dataTypes
```

Screenshot #21

```
asmlinkage long syscalltest_helloworld(void);
asmlinkage long syscalltest_echo(int);
asmlinkage long syscalltest_returnIndividualValues(int, int, int);
asmlinkage long syscalltest_minimum(int, int, int, int);
asmlinkage long syscalltest_maximum(int, int, int, int);
asmlinkage long syscalltest_dataTypes(int);
#endif
```

Screenshot #22

```
usertest0816057@usertest0816057-virtual-machine:/usr/src/linux-5.13.19/systemCallTests/numericalTest$ sudo bash -c  "cat > Makefile"
[sudo] password for usertest0816057:
obj-y := numericalTest.o
```

```
ifeq ($(KBUILD_EXTMOD),)
core-y          += kernel/ certs/ mm/ fs/ ipc/ security/ crypto/ block/ systemCallTests/echoTest/ systemCallTests/numericalTest/
```

Screenshot #23

```
547     x32     pwritev2                compat_sys_pwritev64v2
# This is the end of the legacy x32 range.  Numbers 548 and above are
# not special and are not to be used for x32-specific syscalls.

554     64      syscalltest_helloworld  sys_syscalltest_helloworld
555     64      syscalltest_echo        sys_syscalltest_echo
556     64      syscalltest_returnIndividualValues      sys_syscalltest_returnIndividualValues
557     64      syscalltest_addition    sys_syscalltest_addition
558     64      syscalltest_multiplication      sys_syscalltest_multiplication
559     64      syscalltest_dataTypes   sys_syscalltest_dataTypes
```

Screenshot #24

```
asmlinkage long syscalltest_helloworld(void);
asmlinkage long syscalltest_echo(int);
asmlinkage long syscalltest_returnIndividualValues(int, int, int);
asmlinkage long syscalltest_addition(int, int, int);
asmlinkage long syscalltest_multiplication(int, int, int);
asmlinkage long syscalltest_dataTypes(int);

#endif
```

```
usertest0816057@usertest0816057-virtual-machine:/usr/src/linux-4.19.148$ sudo make install
[sudo] password for usertest0816057:
sh ./arch/x86/boot/install.sh 4.19.148 arch/x86/boot/bzImage \
        System.map "/boot"
run-parts: executing /etc/kernel/postinst.d/apt-auto-removal 4.19.148 /boot/vmlinuz-4.19.148
run-parts: executing /etc/kernel/postinst.d/initramfs-tools 4.19.148 /boot/vmlinuz-4.19.148
update-initramfs: Generating /boot/initrd.img-4.19.148
I: The initramfs will attempt to resume from /dev/sda5
I: (UUID=e55a4a2f-fb90-4a0a-913e-8ff65f7dd177)
I: Set the RESUME variable to override this.
run-parts: executing /etc/kernel/postinst.d/unattended-upgrades 4.19.148 /boot/vmlinuz-4.19.148
run-parts: executing /etc/kernel/postinst.d/update-notifier 4.19.148 /boot/vmlinuz-4.19.148
run-parts: executing /etc/kernel/postinst.d/xx-update-initrd-links 4.19.148 /boot/vmlinuz-4.19.148
I: /boot/vmlinuz.old is now a symlink to vmlinuz-5.13.19
I: /boot/initrd.img.old is now a symlink to initrd.img-5.13.19
I: /boot/vmlinuz is now a symlink to vmlinuz-4.19.148
I: /boot/initrd.img is now a symlink to initrd.img-4.19.148
run-parts: executing /etc/kernel/postinst.d/zz-update-grub 4.19.148 /boot/vmlinuz-4.19.148
Sourcing file `/etc/default/grub'
Sourcing file `/etc/default/grub.d/init-select.cfg'
Generating grub configuration file ...
Found linux image: /boot/vmlinuz-5.13.19
Found initrd image: /boot/initrd.img-5.13.19
Found linux image: /boot/vmlinuz-5.13.19.old
Found initrd image: /boot/initrd.img-5.13.19
Found linux image: /boot/vmlinuz-5.11.0-40-generic
Found initrd image: /boot/initrd.img-5.11.0-40-generic
Found linux image: /boot/vmlinuz-5.11.0-27-generic
Found initrd image: /boot/initrd.img-5.11.0-27-generic
Found linux image: /boot/vmlinuz-4.19.148
Found initrd image: /boot/initrd.img-4.19.148
Found linux image: /boot/vmlinuz-4.19.148.old
Found initrd image: /boot/initrd.img-4.19.148
Found memtest86+ image: /boot/memtest86+.elf
Found memtest86+ image: /boot/memtest86+.bin
done
```

```
usertest0816057@usertest0816057-virtual-machine:/usr/src/linux-5.13.19$ sudo make install
[sudo] password for usertest0816057:
arch/x86/Makefile:148: CONFIG_X86_X32 enabled but no binutils support
sh ./arch/x86/boot/install.sh 5.13.19 arch/x86/boot/bzImage \
        System.map "/boot"
run-parts: executing /etc/kernel/postinst.d/apt-auto-removal 5.13.19 /boot/vmlinuz-5.13.19
run-parts: executing /etc/kernel/postinst.d/initramfs-tools 5.13.19 /boot/vmlinuz-5.13.19
update-initramfs: Generating /boot/initrd.img-5.13.19
I: The initramfs will attempt to resume from /dev/sda5
I: (UUID=e55a4a2f-fb90-4a0a-913e-8ff65f7dd177)
I: Set the RESUME variable to override this.
run-parts: executing /etc/kernel/postinst.d/unattended-upgrades 5.13.19 /boot/vmlinuz-5.13.19
run-parts: executing /etc/kernel/postinst.d/update-notifier 5.13.19 /boot/vmlinuz-5.13.19
run-parts: executing /etc/kernel/postinst.d/xx-update-initrd-links 5.13.19 /boot/vmlinuz-5.13.19
I: /boot/initrd.img.old is now a symlink to initrd.img-4.19.148
I: /boot/initrd.img is now a symlink to initrd.img-5.13.19
run-parts: executing /etc/kernel/postinst.d/zz-update-grub 5.13.19 /boot/vmlinuz-5.13.19
Sourcing file `/etc/default/grub'
Sourcing file `/etc/default/grub.d/init-select.cfg'
Generating grub configuration file ...
Found linux image: /boot/vmlinuz-5.13.19
Found initrd image: /boot/initrd.img-5.13.19
Found linux image: /boot/vmlinuz-5.13.19.old
Found initrd image: /boot/initrd.img-5.13.19
Found linux image: /boot/vmlinuz-5.11.0-40-generic
Found initrd image: /boot/initrd.img-5.11.0-40-generic
Found linux image: /boot/vmlinuz-5.11.0-27-generic
Found initrd image: /boot/initrd.img-5.11.0-27-generic
Found linux image: /boot/vmlinuz-4.19.148
Found initrd image: /boot/initrd.img-4.19.148
Found linux image: /boot/vmlinuz-4.19.148.old
Found initrd image: /boot/initrd.img-4.19.148
Found memtest86+ image: /boot/memtest86+.elf
Found memtest86+ image: /boot/memtest86+.bin
done
```

Screenshot #25

```
usertest0816057@usertest0816057-virtual-machine:~/Desktop/SystemCallsRunTests/numericalRuns$ ./syscallsNumerical
a = [15]
b = [43]
c = [30]
studentId = [816057]

=== Kernel 4.19.148 ===
helloworld : 0
echo : 0
returnIndividualValues : 0
minimum : 15
maximum : 43
dataTypes : 0

=== Kernel 5.13.19 ===
helloworld : -1
echo : -1
returnIndividualValues : -1
addition : -1
substraction : -1
dataTypes : -1
```

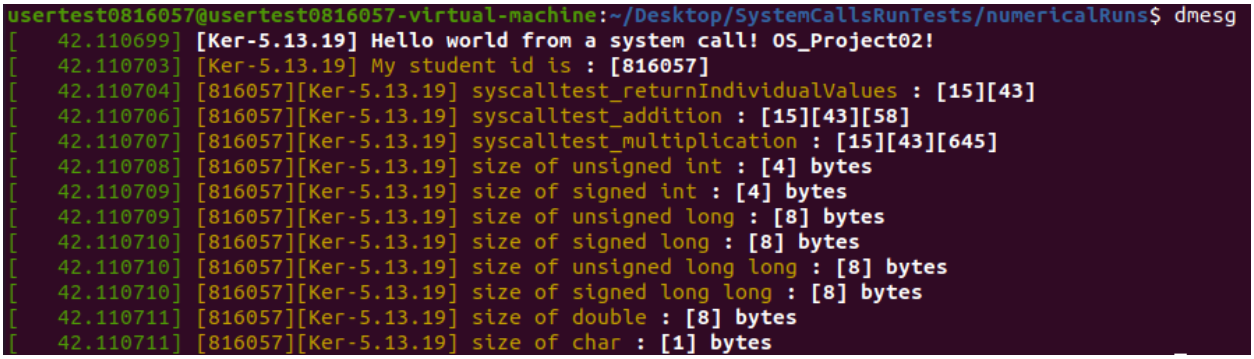
Screenshot #26

```
usertest0816057@usertest0816057-virtual-machine:~/Desktop/SystemCallsRunTests/numericalRuns$ dmesg
[    52.301399] [Ker-4.19.148] Hello world from a system call! - OS_Project02!
[    52.301401] [Ker-4.19.148] My student id is : [816057]
[    52.301402] [816057][Ker-4.19.148] syscalltest_returnIndividualValues : [15][43]
[    52.301403] [816057][Ker-4.19.148] syscalltest_minimum : [15][43][30] - [15]
[    52.301406] [816057][Ker-4.19.148] syscalltest_maximum : [15][43][30] - [43]
[    52.301406] [816057][Ker-4.19.148] size of unsigned int : [4] bytes
[    52.301407] [816057][Ker-4.19.148] size of signed int : [4] bytes
[    52.301433] [816057][Ker-4.19.148] size of unsigned long : [8] bytes
[    52.301434] [816057][Ker-4.19.148] size of signed long : [8] bytes
[    52.301434] [816057][Ker-4.19.148] size of unsigned long long : [8] bytes
[    52.301434] [816057][Ker-4.19.148] size of signed long long : [8] bytes
[    52.301434] [816057][Ker-4.19.148] size of double : [8] bytes
[    52.301435] [816057][Ker-4.19.148] size of char : [1] bytes
usertest0816057@usertest0816057-virtual-machine:~/Desktop/SystemCallsRunTests/numericalRuns$ uname -r
4.19.148
```

Screenshot #27

```
usertest0816057@usertest0816057-virtual-machine:~/Desktop/SystemCallsRunTests/numericalRuns$ uname -r
5.13.19
usertest0816057@usertest0816057-virtual-machine:~/Desktop/SystemCallsRunTests/numericalRuns$ ./syscallsNumerical
a = [15]
b = [43]
c = [30]
studentId = [816057]

=== Kernel 4.19.148 ===
helloworld : -1
echo : -1
returnIndividualValues : -1
minimum : -1
maximum : -1
dataTypes : -1

=== Kernel 5.13.19 ===
helloworld : 0
echo : 0
returnIndividualValues : 0
addition : 58
substraction : 645
dataTypes : 0
```

Screenshot #28



Questions

1.Kernel space 是 Linux 核心的執行空間，User space 是使用者程式的執行空間。彼此隔離，當使用者的程式崩潰時，核心不受影響。Kernel space 可以執行任意命令、呼叫系統的資源，而 User space 只能執行簡單的運算，不能直接呼叫系統資源，必須用 system call 向核心發出指令。

2.protection ring 是一種分級保護的架構，當發生故障時可以保護數據，提升容錯度與安全。Ring 0: Kernel (Highest Privilege), Ring 1: Device Drivers

3.system call: user program 與 OS 之間的溝通介面，當 user program 需要 OS 協助時，呼叫 system call，OS 根據 ID 查表，啟動 service routine 執行並回傳。有五種，功能分別為 Process Control, File Manipulation, Device Manipulation, Information Maintenance, Communication

4. In project01, /usr/src/linux-4.4.101/arch/x86/entry/syscalls/syscall_64.tbl

5. 當 OS 收到 user program 的請求後，根據 ID 查表，執行對應的 system call 並回傳

6. asmlinkage 是個巨集，使用它是為了保持引數在 stack 中。因為從組合語言到 C 語言程式碼引數的傳遞是通過 stack 的。printk: prints messages to the kernel log

7.就像是使用 printf 的方式，只不過 printk 會將 message 寫到 kernel log。用 dmesg 就可以印出 printk 的資訊了

8. kernel ring buffer: a data structure that records messages related to the operation of the kernel.他有固定大小，當新的資料進來時就得會被移除。使用 dmesg 加上一些 option 就可以印出來了

9. function signature : defines input and output of functions or methods, includes the function name, its arguments, and in some languages, the return type

10. n means the number of arguments of the system call 這個 function 有幾個參數就寫多少

11. SYSCALL_DEFINE0([system call name])

SYSCALL_DEFINE1([system call name], int, [int name])

SYSCALL_DEFINE2([system call name], int, [int name 1], int, [int name 2])

SYSCALL_DEFINE3([system call name], int, [int name 1], int, [int name 2], int, [int name 3])

12.it only define the type of input parameters SYSCALL_DEFINE[n]的回傳值由 return 後面的描述決定，只要 return 之後不改變，就算 input parameters 改變也不影響

13.libraries for Linux kernel space usage and Linux system call usage