

# AOS ASSIGNMENT 4

**Name: Madhusree Bera**

**Roll: 2022202007**

Step 1:

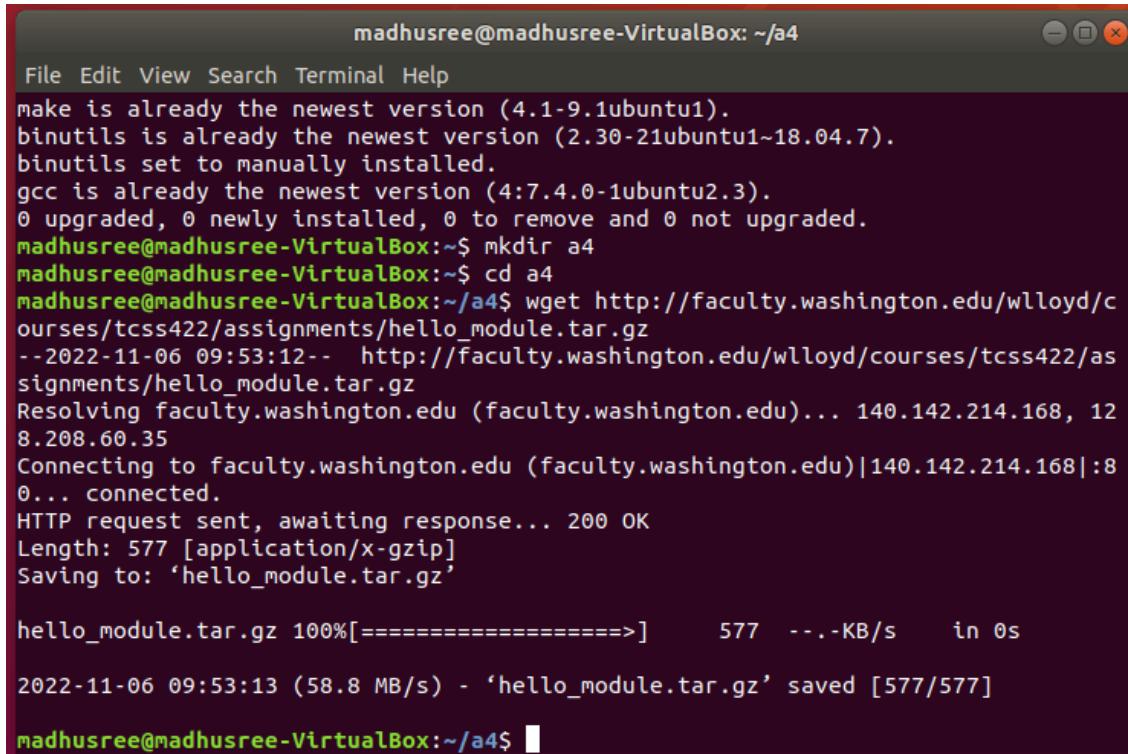
Install essential packages

- make
- binutils
- gcc

```
madhusree@madhusree-VirtualBox:~$ sudo apt install make binutils gcc
Reading package lists... Done
Building dependency tree
Reading state information... Done
make is already the newest version (4.1-9.1ubuntu1).
binutils is already the newest version (2.30-21ubuntu1~18.04.7).
binutils set to manually installed.
gcc is already the newest version (4:7.4.0-1ubuntu2.3).
0 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.
madhusree@madhusree-VirtualBox:~$
```

## Step 2:

Create folder a4, then download the hello\_module starter code from the given link.  
Then extract the files as shown



```
madhusree@madhusree-VirtualBox: ~/a4
File Edit View Search Terminal Help
make is already the newest version (4.1-9.1ubuntu1).
binutils is already the newest version (2.30-21ubuntu1~18.04.7).
binutils set to manually installed.
gcc is already the newest version (4:7.4.0-1ubuntu2.3).
0 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.
madhusree@madhusree-VirtualBox:~$ mkdir a4
madhusree@madhusree-VirtualBox:~$ cd a4
madhusree@madhusree-VirtualBox:~/a4$ wget http://faculty.washington.edu/wlloyd/courses/tcss422/assignments/hello_module.tar.gz
--2022-11-06 09:53:12--  http://faculty.washington.edu/wlloyd/courses/tcss422/assignments/hello_module.tar.gz
Resolving faculty.washington.edu (faculty.washington.edu)... 140.142.214.168, 128.208.60.35
Connecting to faculty.washington.edu (faculty.washington.edu)|140.142.214.168|:80... connected.
HTTP request sent, awaiting response... 200 OK
Length: 577 [application/x-gzip]
Saving to: 'hello_module.tar.gz'

hello_module.tar.gz 100%[=====] 577 --.-KB/s   in 0s

2022-11-06 09:53:13 (58.8 MB/s) - 'hello_module.tar.gz' saved [577/577]

madhusree@madhusree-VirtualBox:~/a4$
```

```
madhusree@madhusree-VirtualBox:~/a4
File Edit View Search Terminal Help
binutils is already the newest version (2.30-21ubuntu1~18.04.7).
binutils set to manually installed.
gcc is already the newest version (4:7.4.0-1ubuntu2.3).
0 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.
madhusree@madhusree-VirtualBox:~$ mkdir a4
madhusree@madhusree-VirtualBox:~$ cd a4
madhusree@madhusree-VirtualBox:~/a4$ wget http://faculty.washington.edu/wlloyd/courses/tcss422/assignments/hello_module.tar.gz
--2022-11-06 09:53:12-- http://faculty.washington.edu/wlloyd/courses/tcss422/assignments/hello_module.tar.gz
Resolving faculty.washington.edu (faculty.washington.edu)... 140.142.214.168, 128.208.60.35
Connecting to faculty.washington.edu (faculty.washington.edu)|140.142.214.168|:80... connected.
HTTP request sent, awaiting response... 200 OK
Length: 577 [application/x-gzip]
Saving to: 'hello_module.tar.gz'

hello_module.tar.gz 100%[=====] 577 --.-KB/s in 0s

2022-11-06 09:53:13 (58.8 MB/s) - 'hello_module.tar.gz' saved [577/577]

madhusree@madhusree-VirtualBox:~/a4$ tar xzf hello_module.tar.gz
madhusree@madhusree-VirtualBox:~/a4$
```

### Step 3:

After extracting the files, go to hello\_module folder and examine the files

```
madhusree@madhusree-VirtualBox:~/a4/hello_module
File Edit View Search Terminal Help
binutils set to manually installed.
gcc is already the newest version (4:7.4.0-1ubuntu2.3).
0 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.
madhusree@madhusree-VirtualBox:~$ mkdir a4
madhusree@madhusree-VirtualBox:~$ cd a4
madhusree@madhusree-VirtualBox:~/a4$ wget http://faculty.washington.edu/wlloyd/courses/tcss422/assignments/hello_module.tar.gz
--2022-11-06 09:53:12-- http://faculty.washington.edu/wlloyd/courses/tcss422/assignments/hello_module.tar.gz
Resolving faculty.washington.edu (faculty.washington.edu)... 140.142.214.168, 128.208.60.35
Connecting to faculty.washington.edu (faculty.washington.edu)|140.142.214.168|:80... connected.
HTTP request sent, awaiting response... 200 OK
Length: 577 [application/x-gzip]
Saving to: 'hello_module.tar.gz'

hello_module.tar.gz 100%[=====] 577 --.-KB/s in 0s

2022-11-06 09:53:13 (58.8 MB/s) - 'hello_module.tar.gz' saved [577/577]

madhusree@madhusree-VirtualBox:~/a4$ tar xzf hello_module.tar.gz
madhusree@madhusree-VirtualBox:~/a4$ cd hello_module/
madhusree@madhusree-VirtualBox:~/a4/hello_module$
```

```
madhusree@madhusree-VirtualBox: ~/a4/hello_module
File Edit View Search Terminal Help
8.208.60.35
Connecting to faculty.washington.edu (faculty.washington.edu)|140.142.214.168|:8
0... connected.
HTTP request sent, awaiting response... 200 OK
Length: 577 [application/x-gzip]
Saving to: 'hello_module.tar.gz'

hello_module.tar.gz 100%[=====] 577 --.-KB/s in 0s

2022-11-06 09:53:13 (58.8 MB/s) - 'hello_module.tar.gz' saved [577/577]

madhusree@madhusree-VirtualBox:~/a4$ tar xzf hello_module.tar.gz
madhusree@madhusree-VirtualBox:~/a4$ cd hello_module/
madhusree@madhusree-VirtualBox:~/a4/hello_module$ ls -la
total 16
drwxr-xr-x 2 madhusree madhusree 4096 May 30 2020 .
drwxrwxr-x 3 madhusree madhusree 4096 Nov 6 09:53 ..
-rw-r--r-- 1 madhusree madhusree 541 May 30 2020 helloModule.c
-rw-r--r-- 1 madhusree madhusree 182 Oct 24 2016 Makefile
madhusree@madhusree-VirtualBox:~/a4/hello_module$ ls -l
total 8
-rw-r--r-- 1 madhusree madhusree 541 May 30 2020 helloModule.c
-rw-r--r-- 1 madhusree madhusree 182 Oct 24 2016 Makefile
madhusree@madhusree-VirtualBox:~/a4/hello_module$
```

The hello\_module contains “helloModule.c”, which includes source code for the most basic Linux kernel module. Inspect the code. The module consists of an initialization method and a cleanup method. The initialization method is triggered automatically as an “event” when the module is loaded. The cleanup method is triggered when the kernel module is unloaded. Kernel modules are loaded dynamically into the operating system.

## Step 4:

Compile the kernel using make command

```
madhusree@madhusree-VirtualBox: ~/a4/hello_module
File Edit View Search Terminal Help

madhusree@madhusree-VirtualBox:~/a4$ tar xzf hello_module.tar.gz
madhusree@madhusree-VirtualBox:~/a4$ cd hello_module/
madhusree@madhusree-VirtualBox:~/a4/hello_module$ ls -la
total 16
drwxr-xr-x 2 madhusree madhusree 4096 May 30 2020 .
drwxrwxr-x 3 madhusree madhusree 4096 Nov  6 09:53 ..
-rw-r--r-- 1 madhusree madhusree  541 May 30 2020 helloModule.c
-rw-r--r-- 1 madhusree madhusree 182 Oct 24 2016 Makefile
madhusree@madhusree-VirtualBox:~/a4/hello_module$ ls -l
total 8
-rw-r--r-- 1 madhusree madhusree 541 May 30 2020 helloModule.c
-rw-r--r-- 1 madhusree madhusree 182 Oct 24 2016 Makefile
madhusree@madhusree-VirtualBox:~/a4/hello_module$ make
make -C /lib/modules/5.4.0-125-generic/build M=/home/madhusree/a4/hello_module modules
make[1]: Entering directory '/usr/src/linux-headers-5.4.0-125-generic'
  CC [M] /home/madhusree/a4/hello_module/helloModule.o
  Building modules, stage 2.
  MODPOST 1 modules
  CC [M] /home/madhusree/a4/hello_module/helloModule.mod.o
  LD [M] /home/madhusree/a4/hello_module/helloModule.ko
make[1]: Leaving directory '/usr/src/linux-headers-5.4.0-125-generic'
madhusree@madhusree-VirtualBox:~/a4/hello_module$
```

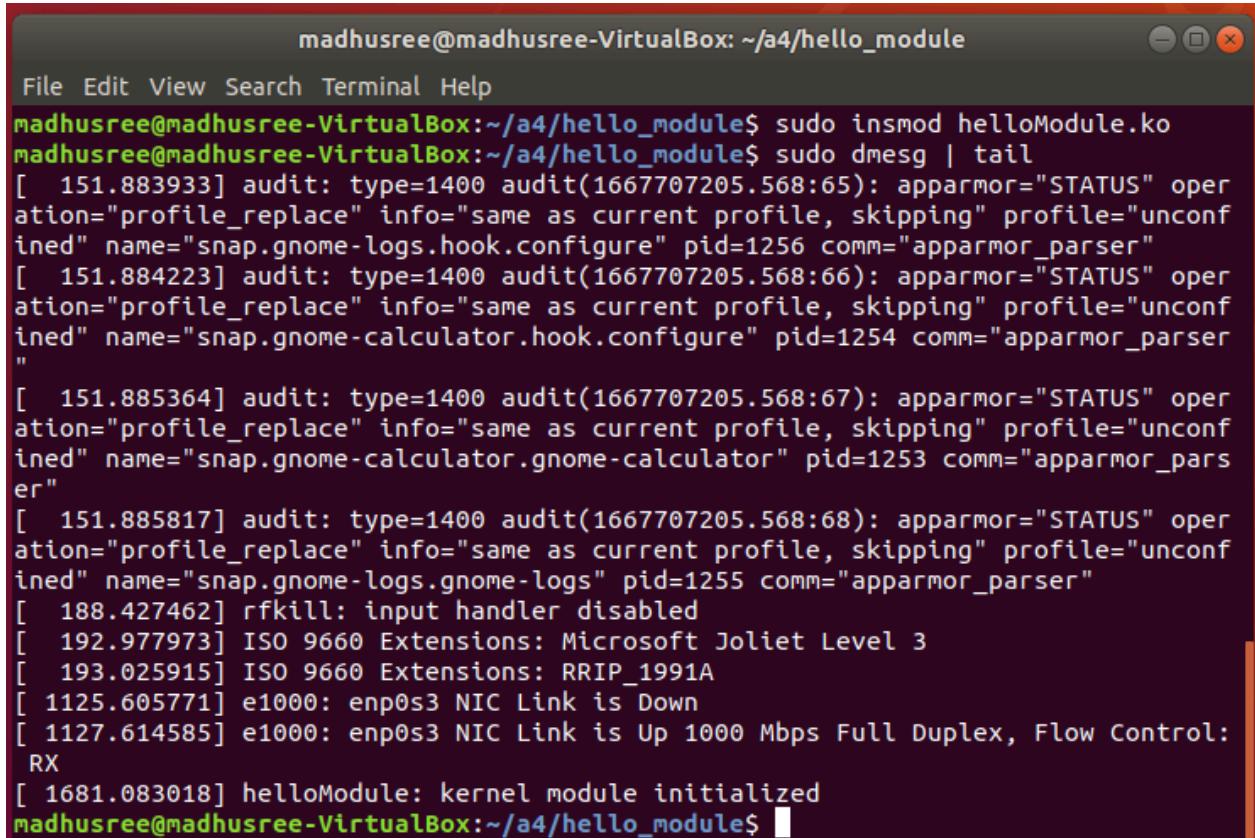
## Step 5:

Load the kernel object file using insmod command

```
madhusree@madhusree-VirtualBox: ~/a4/hello_module
File Edit View Search Terminal Help
madhusree@madhusree-VirtualBox:~/a4$ tar xzf hello_module.tar.gz
madhusree@madhusree-VirtualBox:~/a4$ cd hello_module/
madhusree@madhusree-VirtualBox:~/a4/hello_module$ ls -la
total 16
drwxr-xr-x 2 madhusree madhusree 4096 May 30 2020 .
drwxrwxr-x 3 madhusree madhusree 4096 Nov 6 09:53 ..
-rw-r--r-- 1 madhusree madhusree 541 May 30 2020 helloModule.c
-rw-r--r-- 1 madhusree madhusree 182 Oct 24 2016 Makefile
madhusree@madhusree-VirtualBox:~/a4/hello_module$ ls -l
total 8
-rw-r--r-- 1 madhusree madhusree 541 May 30 2020 helloModule.c
-rw-r--r-- 1 madhusree madhusree 182 Oct 24 2016 Makefile
madhusree@madhusree-VirtualBox:~/a4/hello_module$ make
make -C /lib/modules/5.4.0-125-generic/build M=/home/madhusree/a4/hello_module modules
make[1]: Entering directory '/usr/src/linux-headers-5.4.0-125-generic'
CC [M] /home/madhusree/a4/hello_module/helloModule.o
Building modules, stage 2.
MODPOST 1 modules
CC [M] /home/madhusree/a4/hello_module/helloModule.mod.o
LD [M] /home/madhusree/a4/hello_module/helloModule.ko
make[1]: Leaving directory '/usr/src/linux-headers-5.4.0-125-generic'
madhusree@madhusree-VirtualBox:~/a4/hello_module$ sudo insmod helloModule.ko
madhusree@madhusree-VirtualBox:~/a4/hello_module$
```

## Step 6:

Check the last 10 line of logs using tail command.



The screenshot shows a terminal window titled "madhusree@madhusree-VirtualBox: ~/a4/hello\_module". The window contains the following text:

```
madhusree@madhusree-VirtualBox:~/a4/hello_module$ sudo insmod helloModule.ko
madhusree@madhusree-VirtualBox:~/a4/hello_module$ sudo dmesg | tail
[ 151.883933] audit: type=1400 audit(1667707205.568:65): apparmor="STATUS" operation="profile_replace" info="same as current profile, skipping" profile="unconfined" name="snap.gnome-logs.hook.configure" pid=1256 comm="apparmor_parser"
[ 151.884223] audit: type=1400 audit(1667707205.568:66): apparmor="STATUS" operation="profile_replace" info="same as current profile, skipping" profile="unconfined" name="snap.gnome-calculator.hook.configure" pid=1254 comm="apparmor_parser"
[ 151.885364] audit: type=1400 audit(1667707205.568:67): apparmor="STATUS" operation="profile_replace" info="same as current profile, skipping" profile="unconfined" name="snap.gnome-calculator.gnome-calculator" pid=1253 comm="apparmor_parser"
[ 151.885817] audit: type=1400 audit(1667707205.568:68): apparmor="STATUS" operation="profile_replace" info="same as current profile, skipping" profile="unconfined" name="snap.gnome-logs.gnome-logs" pid=1255 comm="apparmor_parser"
[ 188.427462] rfkill: input handler disabled
[ 192.977973] ISO 9660 Extensions: Microsoft Joliet Level 3
[ 193.025915] ISO 9660 Extensions: RRIP_1991A
[ 1125.605771] e1000: enp0s3 NIC Link is Down
[ 1127.614585] e1000: enp0s3 NIC Link is Up 1000 Mbps Full Duplex, Flow Control: RX
[ 1681.083018] helloModule: kernel module initialized
madhusree@madhusree-VirtualBox:~/a4/hello_module$
```

## Step 7:

Unload the module using rmmod command, then compile the kernel

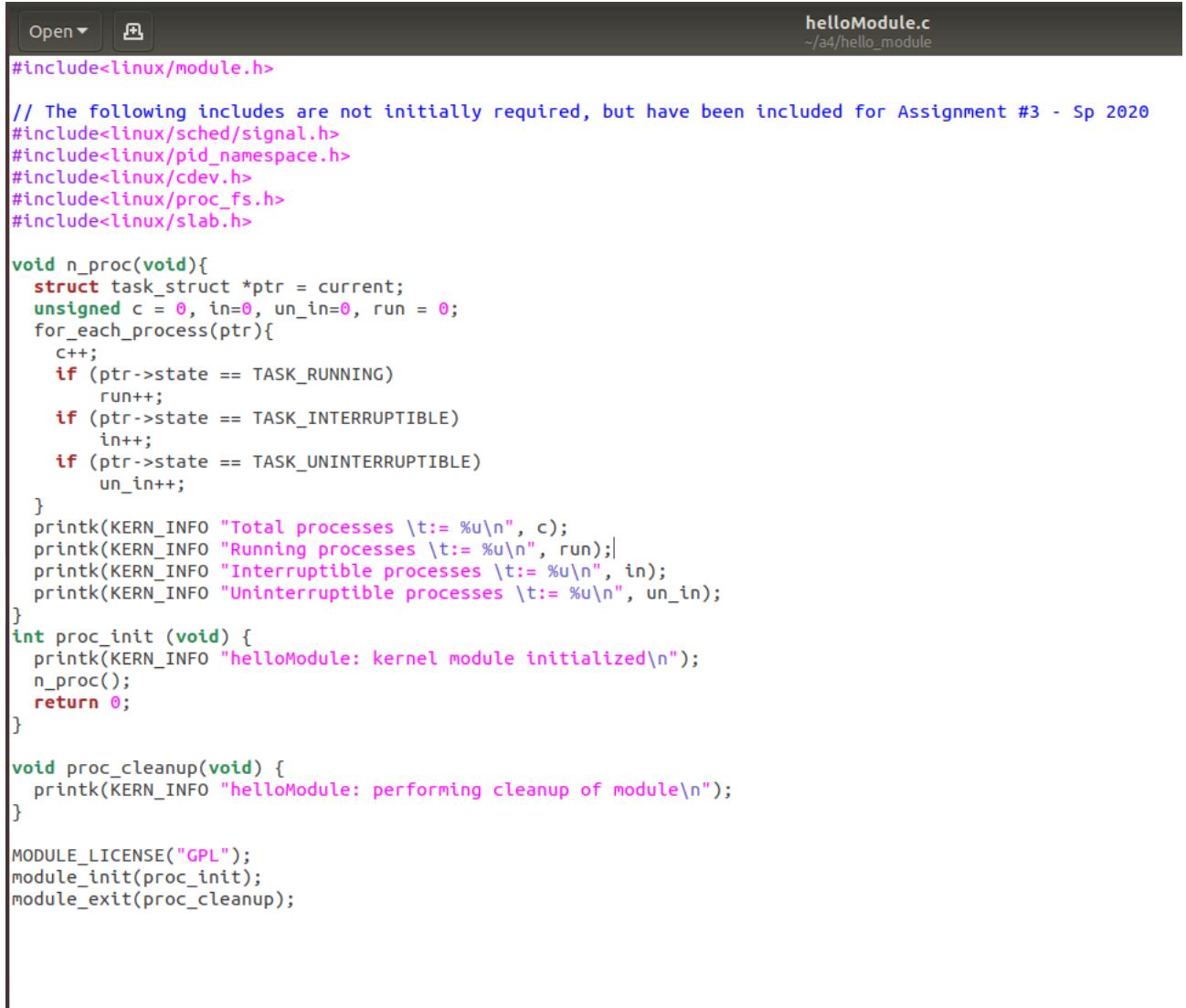
```
madhusree@madhusree-VirtualBox: ~/a4/hello_module
File Edit View Search Terminal Help
madhusree@madhusree-VirtualBox:~/a4/hello_module$ sudo dmesg | tail
[ 151.883933] audit: type=1400 audit(1667707205.568:65): apparmor="STATUS" operation="profile_replace" info="same as current profile, skipping" profile="unconfined" name="snap.gnome-logs.hook.configure" pid=1256 comm="apparmor_parser"
[ 151.884223] audit: type=1400 audit(1667707205.568:66): apparmor="STATUS" operation="profile_replace" info="same as current profile, skipping" profile="unconfined" name="snap.gnome-calculator.hook.configure" pid=1254 comm="apparmor_parser"
[ 151.885364] audit: type=1400 audit(1667707205.568:67): apparmor="STATUS" operation="profile_replace" info="same as current profile, skipping" profile="unconfined" name="snap.gnome-calculator.gnome-calculator" pid=1253 comm="apparmor_parser"
[ 151.885817] audit: type=1400 audit(1667707205.568:68): apparmor="STATUS" operation="profile_replace" info="same as current profile, skipping" profile="unconfined" name="snap.gnome-logs.gnome-logs" pid=1255 comm="apparmor_parser"
[ 188.427462] rfkill: input handler disabled
[ 192.977973] ISO 9660 Extensions: Microsoft Joliet Level 3
[ 193.025915] ISO 9660 Extensions: RRIP_1991A
[ 1125.605771] e1000: enp0s3 NIC Link is Down
[ 1127.614585] e1000: enp0s3 NIC Link is Up 1000 Mbps Full Duplex, Flow Control: RX
[ 1681.083018] helloModule: kernel module initialized
madhusree@madhusree-VirtualBox:~/a4/hello_module$ sudo rmmod helloModule
madhusree@madhusree-VirtualBox:~/a4/hello_module$
```

```
madhusree@madhusree-VirtualBox:~/a4/hello_module$ make
make -C /lib/modules/5.4.0-125-generic/build M=/home/madhusree/a4/hello_module modules
make[1]: Entering directory '/usr/src/linux-headers-5.4.0-125-generic'
Building modules, stage 2.
MODPOST 1 modules
make[1]: Leaving directory '/usr/src/linux-headers-5.4.0-125-generic'
madhusree@madhusree-VirtualBox:~/a4/hello_module$
```

## Step 8:

Change the helloModule.c file and write the code for counting

- # Total processes
- # running processes
- # interruptible processes
- # uninterruptible processes



The screenshot shows a code editor window with the file "helloModule.c" open. The title bar indicates the file name and its location (~/a4/hello\_module). The code itself is a Linux kernel module (C code) that counts the number of processes in different states. It includes includes for module.h, sched/signal.h, pid\_namespace.h, cdev.h, proc\_fs.h, and slab.h. The main function, n\_proc, iterates through all tasks and increments counters for running, interruptible, and uninterruptible processes. It then prints these counts using printk. The module also has proc\_init and proc\_cleanup functions. Finally, it defines the MODULE\_LICENSE as GPL and registers the module with module\_init and module\_exit.

```
Open ▾  helloModule.c
~/a4/hello_module

#include<linux/module.h>

// The following includes are not initially required, but have been included for Assignment #3 - Sp 2020
#include<linux/sched/signal.h>
#include<linux/pid_namespace.h>
#include<linux/cdev.h>
#include<linux/proc_fs.h>
#include<linux/slab.h>

void n_proc(void){
    struct task_struct *ptr = current;
    unsigned c = 0, in=0, un_in=0, run = 0;
    for_each_process(ptr){
        c++;
        if (ptr->state == TASK_RUNNING)
            run++;
        if (ptr->state == TASK_INTERRUPTIBLE)
            in++;
        if (ptr->state == TASK_UNINTERRUPTIBLE)
            un_in++;
    }
    printk(KERN_INFO "Total processes \t:= %u\n", c);
    printk(KERN_INFO "Running processes \t:= %u\n", run);
    printk(KERN_INFO "Interruptible processes \t:= %u\n", in);
    printk(KERN_INFO "Uninterruptible processes \t:= %u\n", un_in);
}
int proc_init (void) {
    printk(KERN_INFO "helloModule: kernel module initialized\n");
    n_proc();
    return 0;
}

void proc_cleanup(void) {
    printk(KERN_INFO "helloModule: performing cleanup of module\n");
}

MODULE_LICENSE("GPL");
module_init(proc_init);
module_exit(proc_cleanup);
```

## Step 9:

Compile the kernel using make command load the module using insmod command

```
madhusree@madhusree-VirtualBox:~/a4/hello_module$ make
make -C /lib/modules/5.4.0-125-generic/build M=/home/madhusree/a4/hello_module m
odules
make[1]: Entering directory '/usr/src/linux-headers-5.4.0-125-generic'
  CC [M]  /home/madhusree/a4/hello_module/helloModule.o
  Building modules, stage 2.
  MODPOST 1 modules
  CC [M]  /home/madhusree/a4/hello_module/helloModule.mod.o
  LD [M]  /home/madhusree/a4/hello_module/helloModule.ko
make[1]: Leaving directory '/usr/src/linux-headers-5.4.0-125-generic'
madhusree@madhusree-VirtualBox:~/a4/hello_module$
```

```
madhusree@madhusree-VirtualBox:~/a4/hello_module$ make
make -C /lib/modules/5.4.0-125-generic/build M=/home/madhusree/a4/hello_module m
odules
make[1]: Entering directory '/usr/src/linux-headers-5.4.0-125-generic'
  CC [M]  /home/madhusree/a4/hello_module/helloModule.o
  Building modules, stage 2.
  MODPOST 1 modules
  CC [M]  /home/madhusree/a4/hello_module/helloModule.mod.o
  LD [M]  /home/madhusree/a4/hello_module/helloModule.ko
make[1]: Leaving directory '/usr/src/linux-headers-5.4.0-125-generic'
madhusree@madhusree-VirtualBox:~/a4/hello_module$ sudo insmod helloModule.ko
madhusree@madhusree-VirtualBox:~/a4/hello_module$
```

## Step 10:

check the logs using dmesg command

```
[ 1223.000001] Uninterruptible processes      : 0
[ 1424.667971] helloModule: performing cleanup of module
[ 1447.990883] helloModule: kernel module initialized
[ 1447.990983] Total processes := 213
[ 1447.990984] Running processes := 2
[ 1447.990985] Interruptible processes := 164
[ 1447.990986] Uninterruptible processes := 0
madhusree@madhusree-VirtualBox:~/a4/hello_module$
```