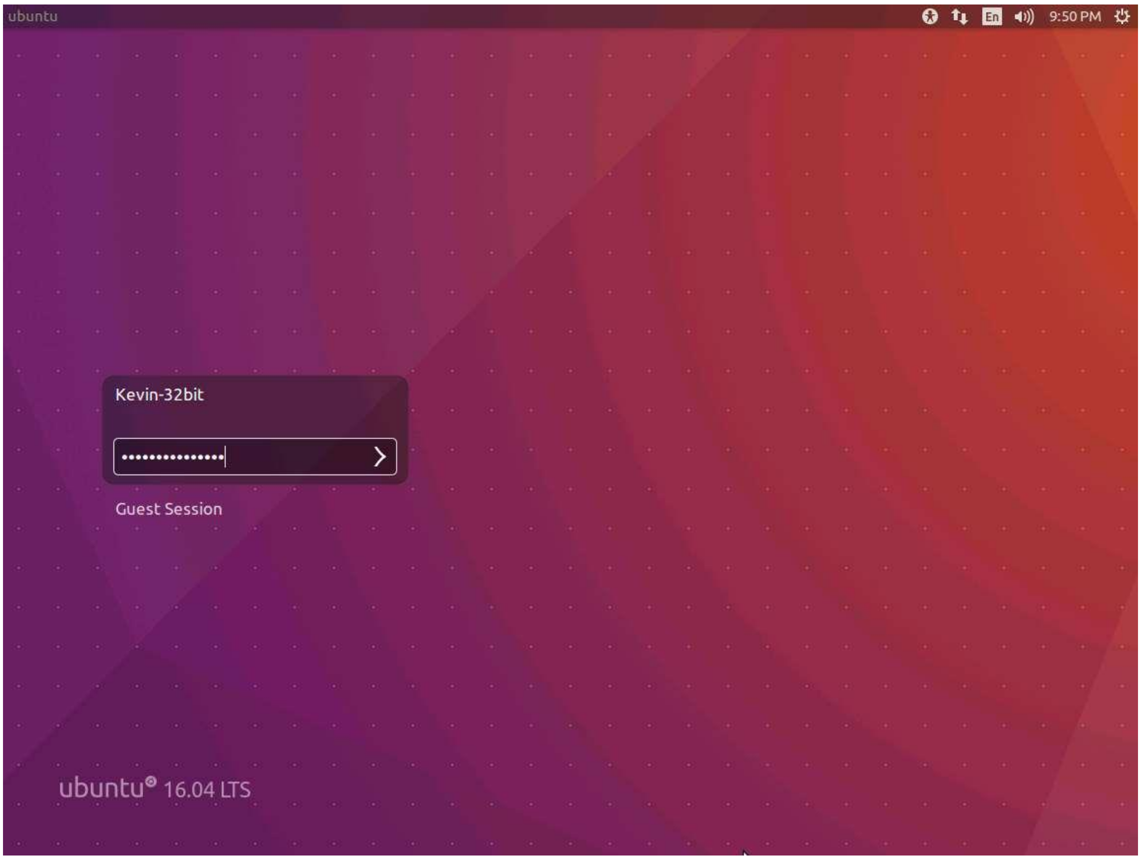
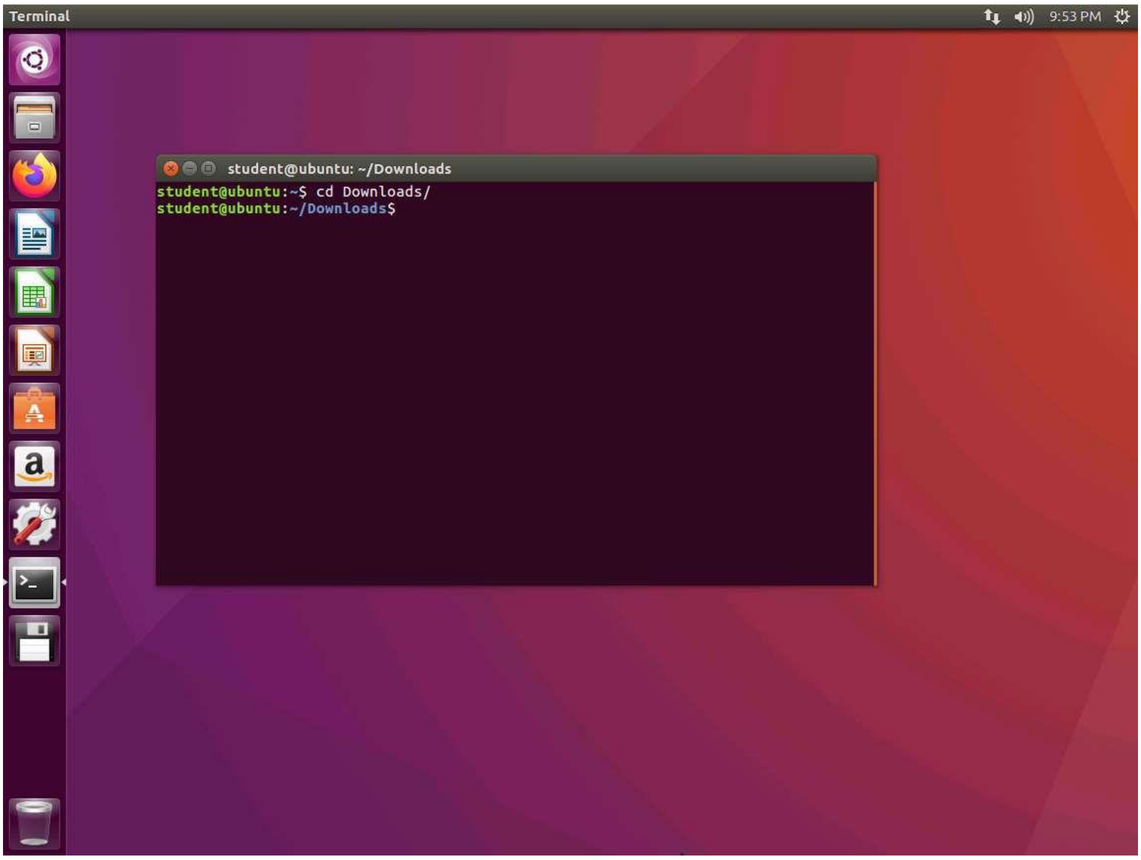
Module 13: Binary Analysis and Exploitation

Exercise 1: Binary Analysis

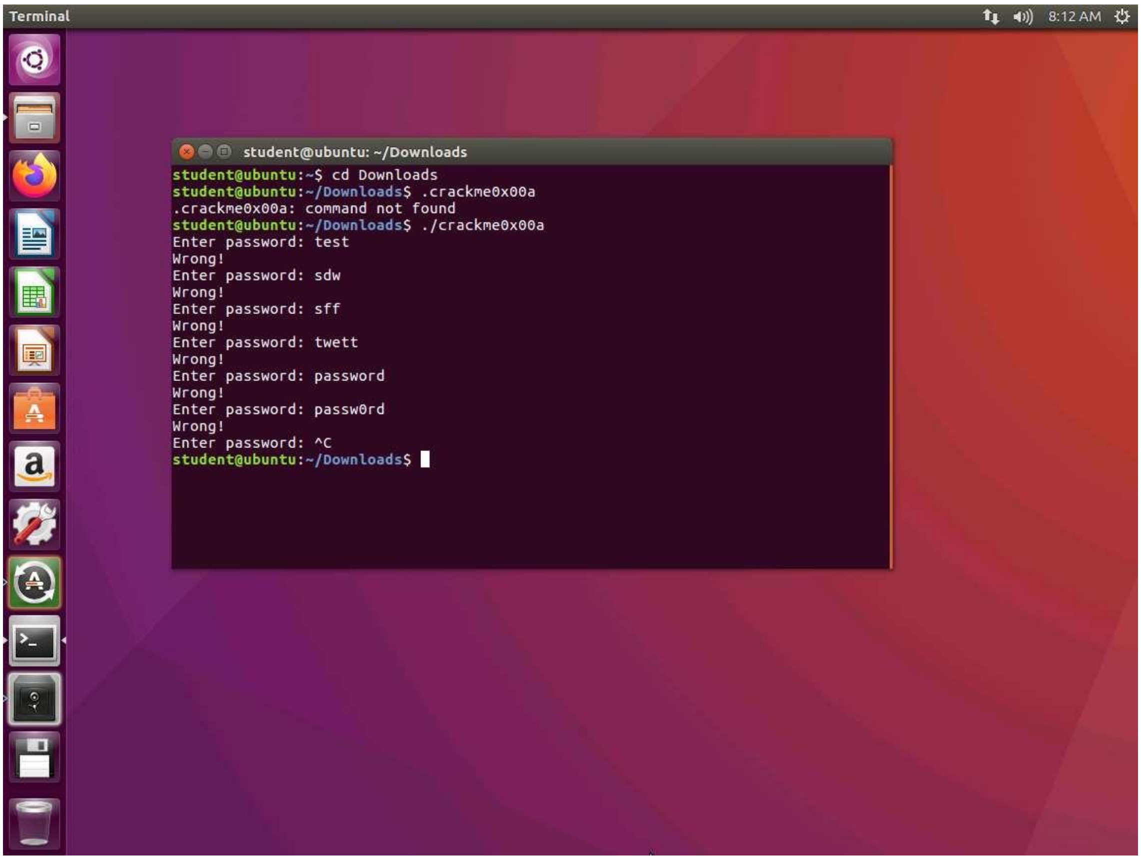
1. ☐ Login to the Software-Test-Linux-32bit machine using **studentpassword** as Password.



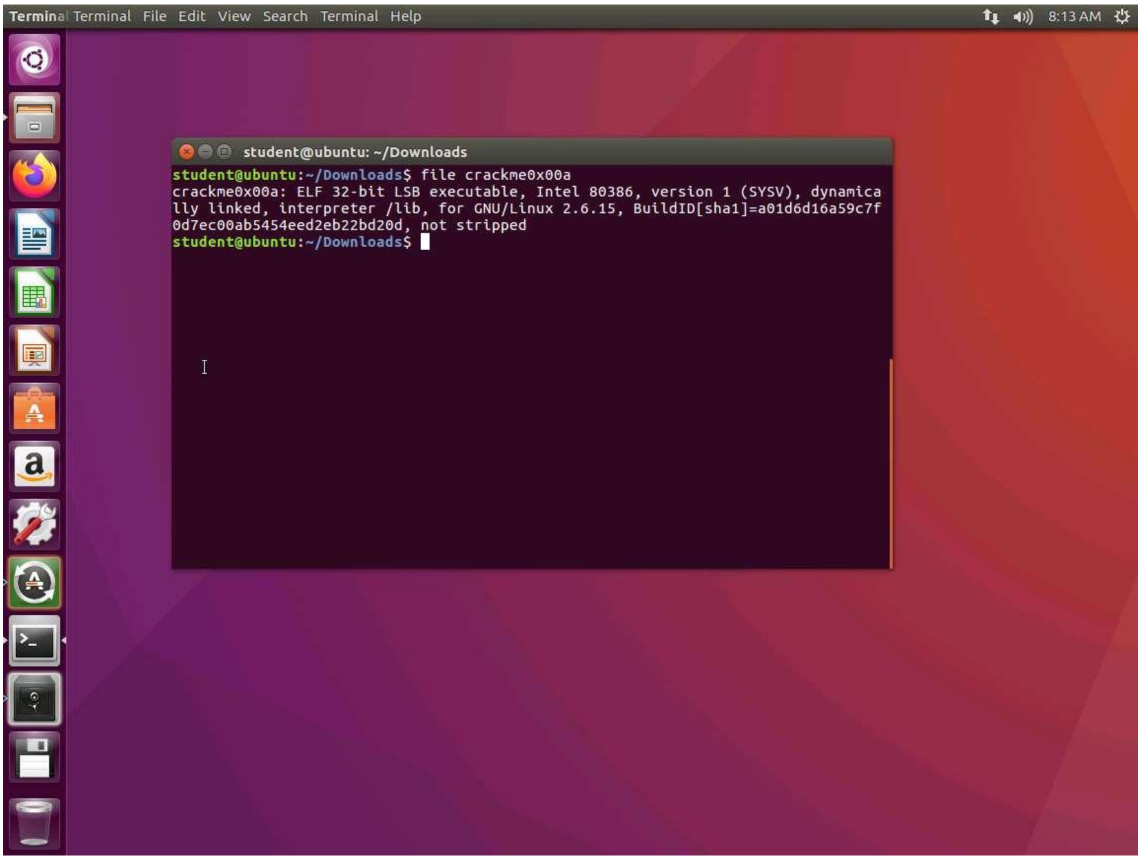
2. ☐ Open a terminal window, and enter **cd Downloads**.



3. Once you are in the folder, enter **./crackme0x00a**. In the 64-bit machine, the program will not run since it is not built for 64 bit, so we will continue with the 32-bit machine for now. Once you run the program, enter some passwords to see if you can determine what the password is. An example of this is shown in the following screenshot.

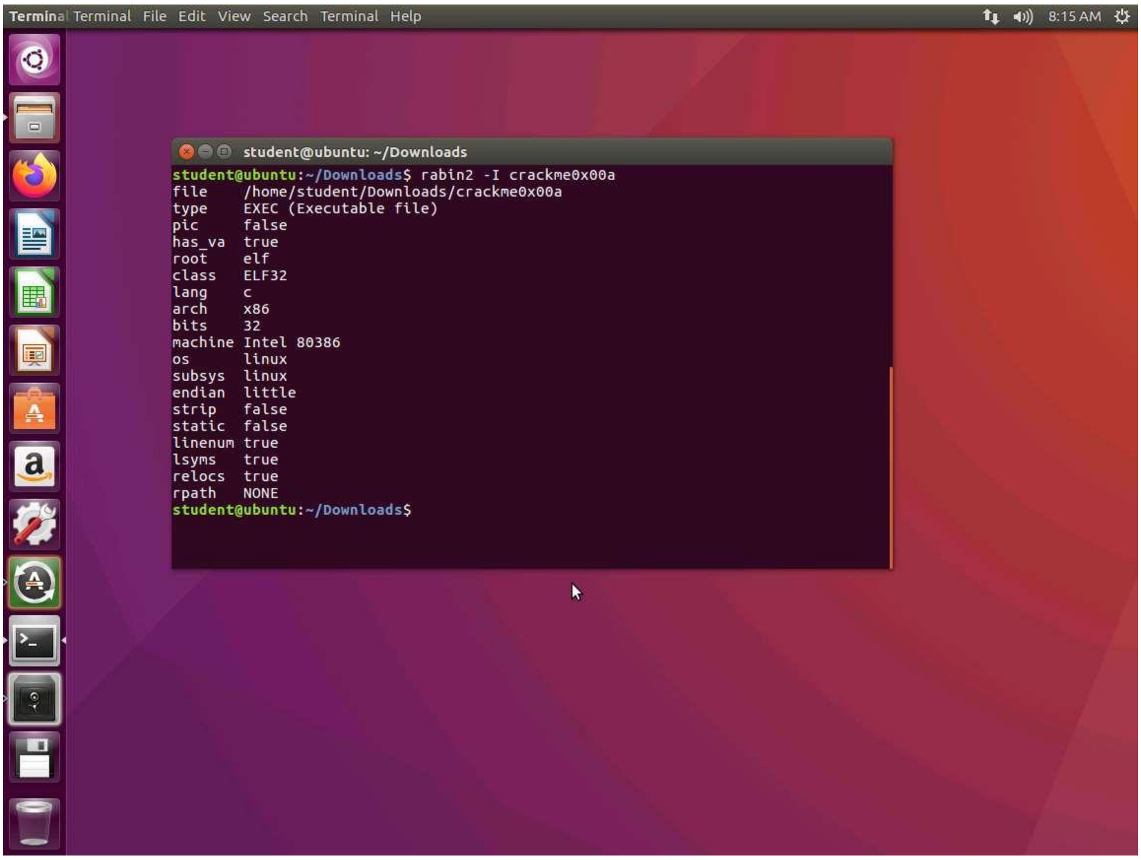


4. ☐ Since we could not guess it, we now need to perform an analysis and see what we can learn about the file. We will use the file command. Enter **file crackme0x00a**. The output of this command is shown in the following screenshot.

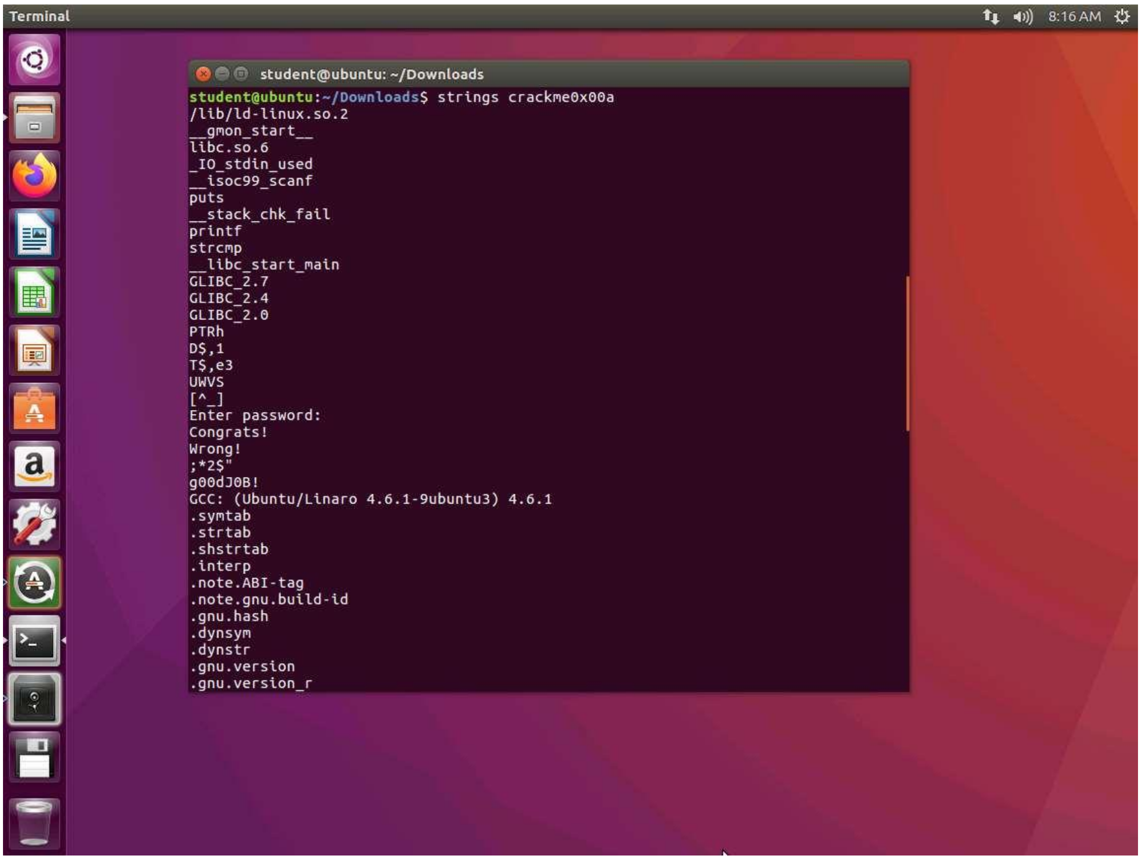


5. ☐ As the above screenshot shows, we have an executable and linking format (ELF) 32 bit executable. The file is 32-bit, LSB executable (least-significant byte). It means that the file is little-endian.

6. ☐ We will use another tool. Enter **rabin2 -I crackme0x00a**. An example of the output of this command is shown in the following screenshot.

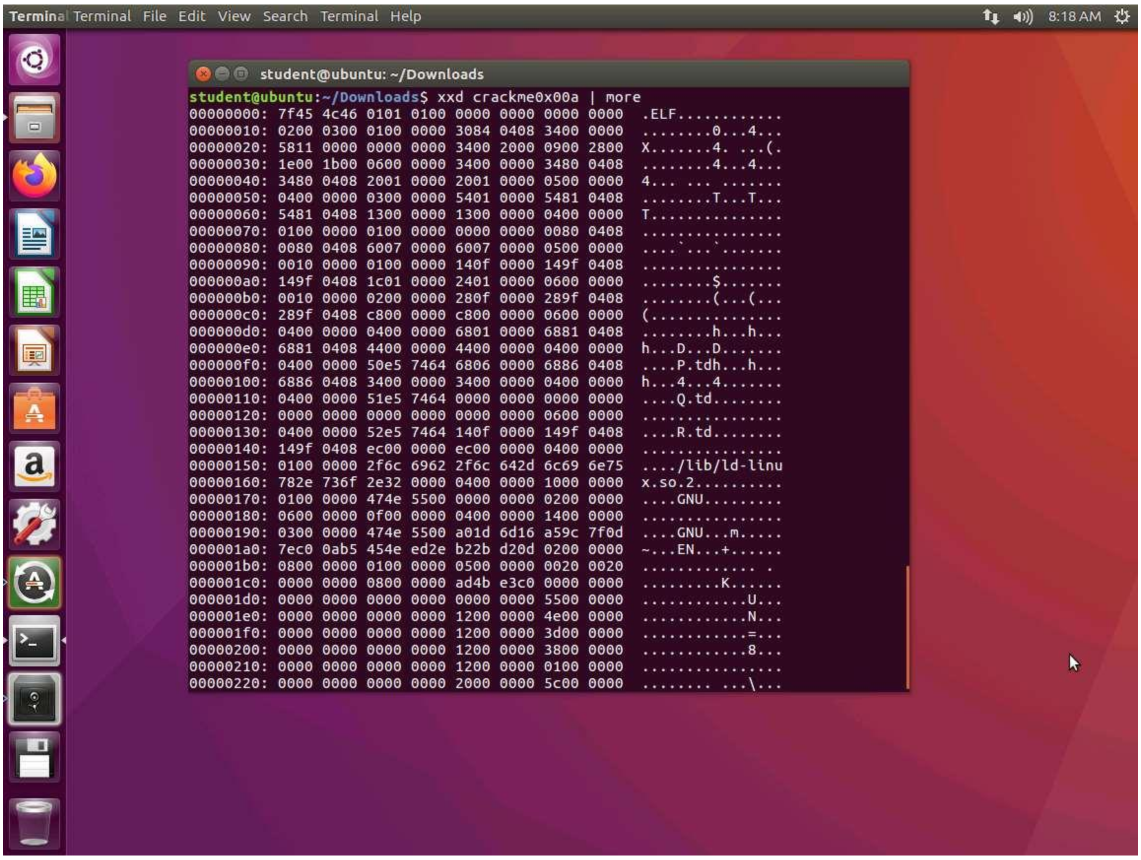


7. ☐ Let us now use powerful tool strings to see what we can discover in the binary. Enter **strings crackme0x00a**. An example of the output of this command is shown in the following screenshot.



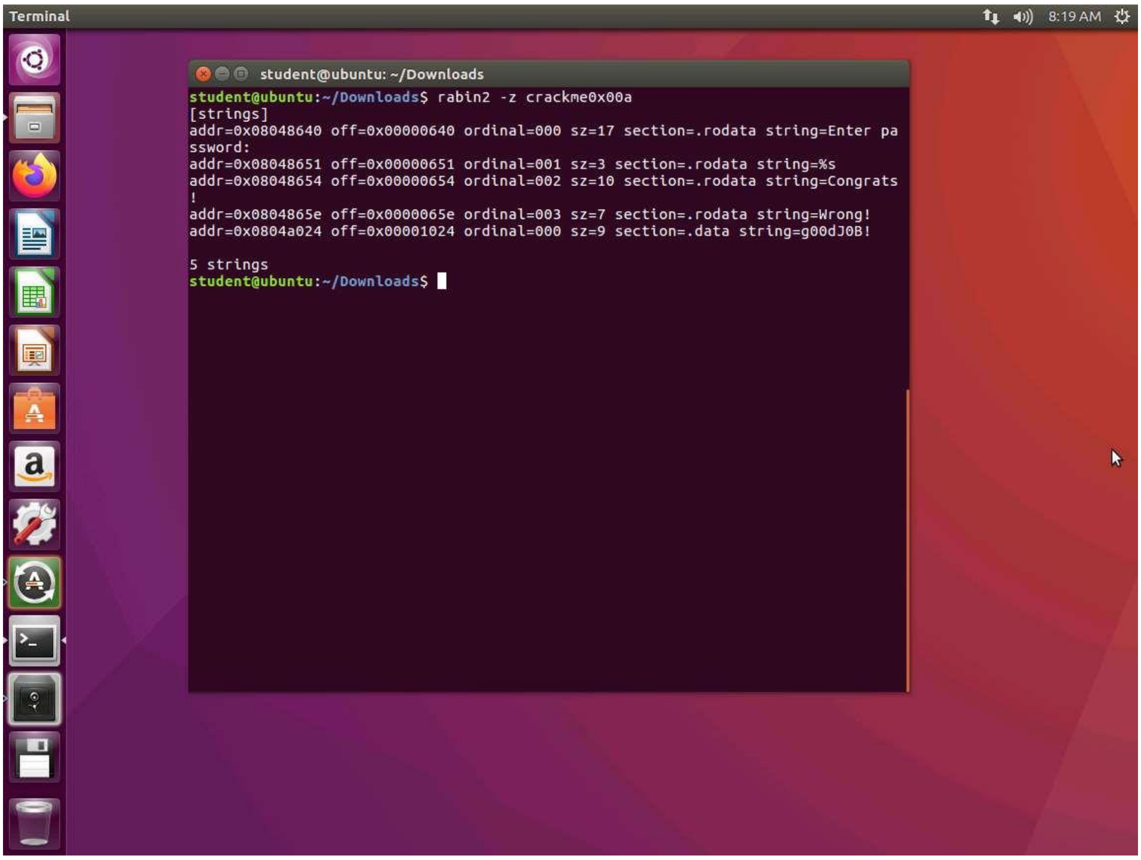
8. ☐ As you review the strings, do you see anything of interest? We have the prompt for the password followed by what appears to be two responses and then a string. This could be the password, but it seems too easy. We will continue to explore the file further.

9. ☐ In the terminal window, enter **xxd crackme0x00a | more**. The output of this command is shown in the following screenshot.

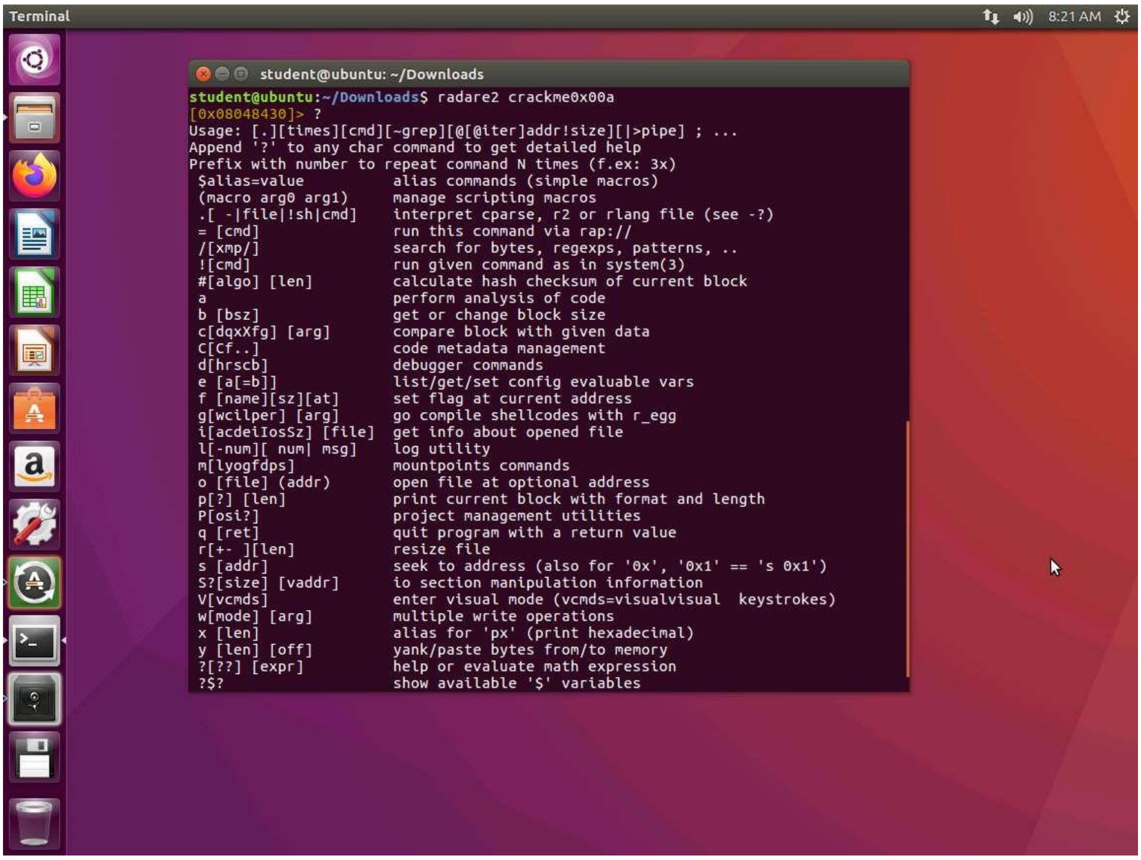


10. ☐ To use rabin2 to crack the file, you will need to execute with a different parameter than the one we used at the information gathering process. If you refer to the manual, you will see that the parameter **-z** is used to show strings inside **.data** section (similar to gnu strings).

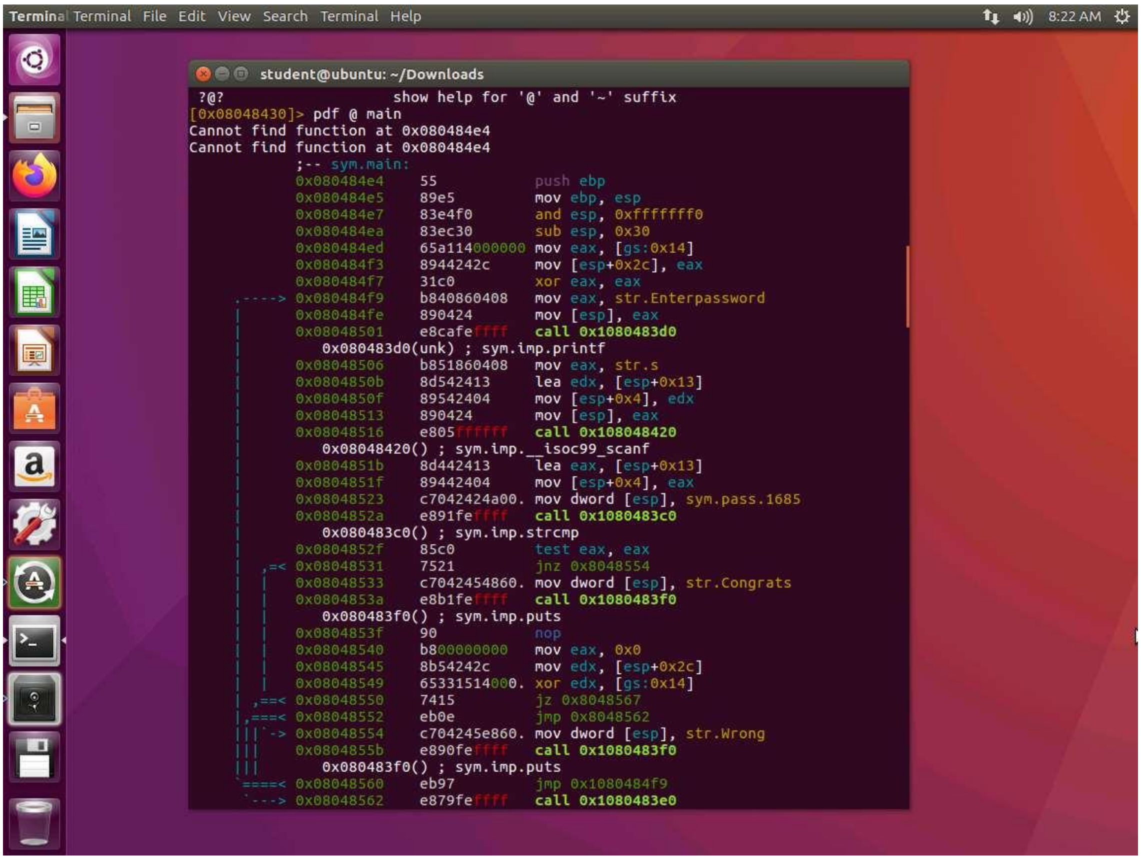
11. ☐ In the terminal window, enter **rabin2 -z crackme0x00a**. An example of this is shown in the following screenshot.



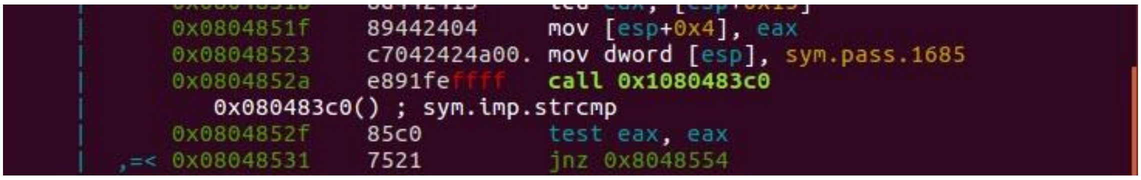
12. ☐ Next, we will use the Radare2 tool to look at the executable. In the terminal window, enter **radare2 crackme0x00a**. Once the program is entered, enter **?**. This will allow you to review the different options. An example of the output of this command is shown in the following screenshot.



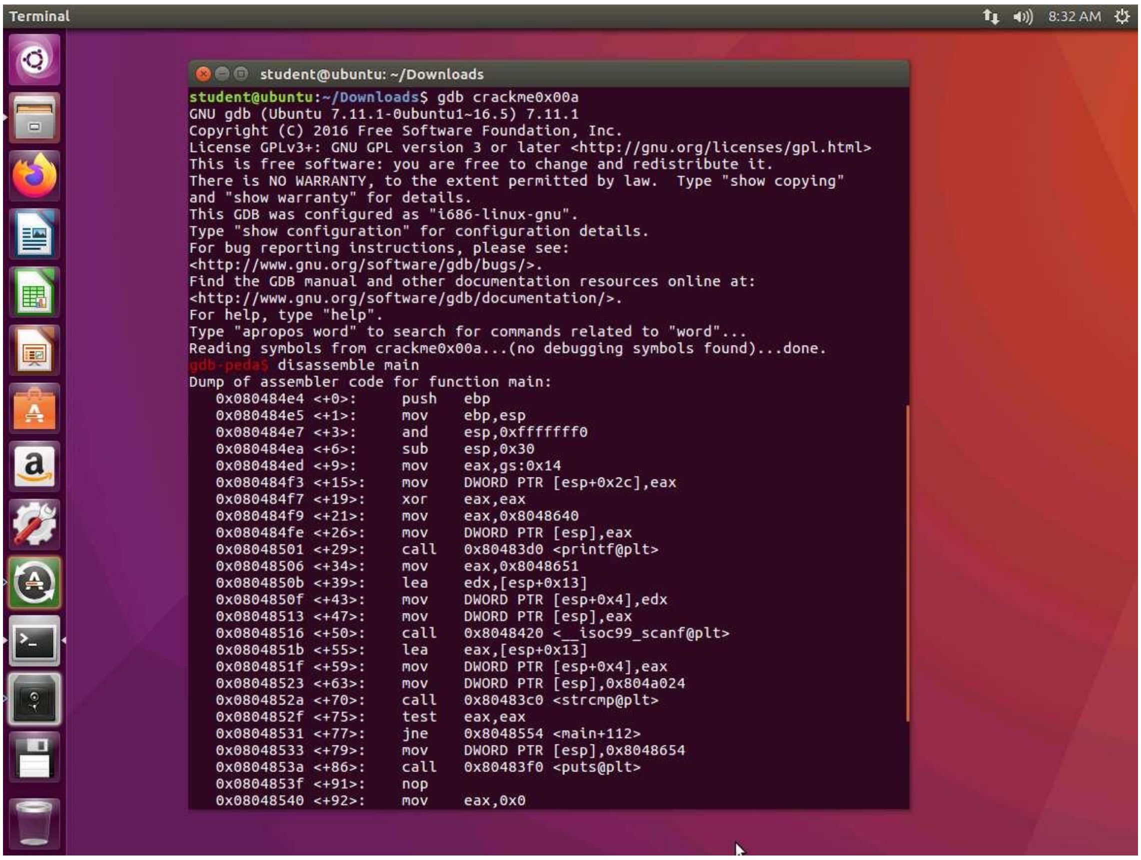
13. ☐ We now want to run the disassemble function. Enter **pdf @ main**. The output of this command is shown in the following screenshot.



14. ☐ Take a few minutes and look through the disassembled code. An example of this is **strcmp**, which is where our password is evaluated. Please check the following screenshot.



15. ☐ We want to look at the code with another tool, which we will now explore. In the terminal window, exit from Radare2 and enter **gdb crackme0x00a**. This will load the executable. Next, enter **disassemble main**. An example of the output of this command is shown in the following screenshot.

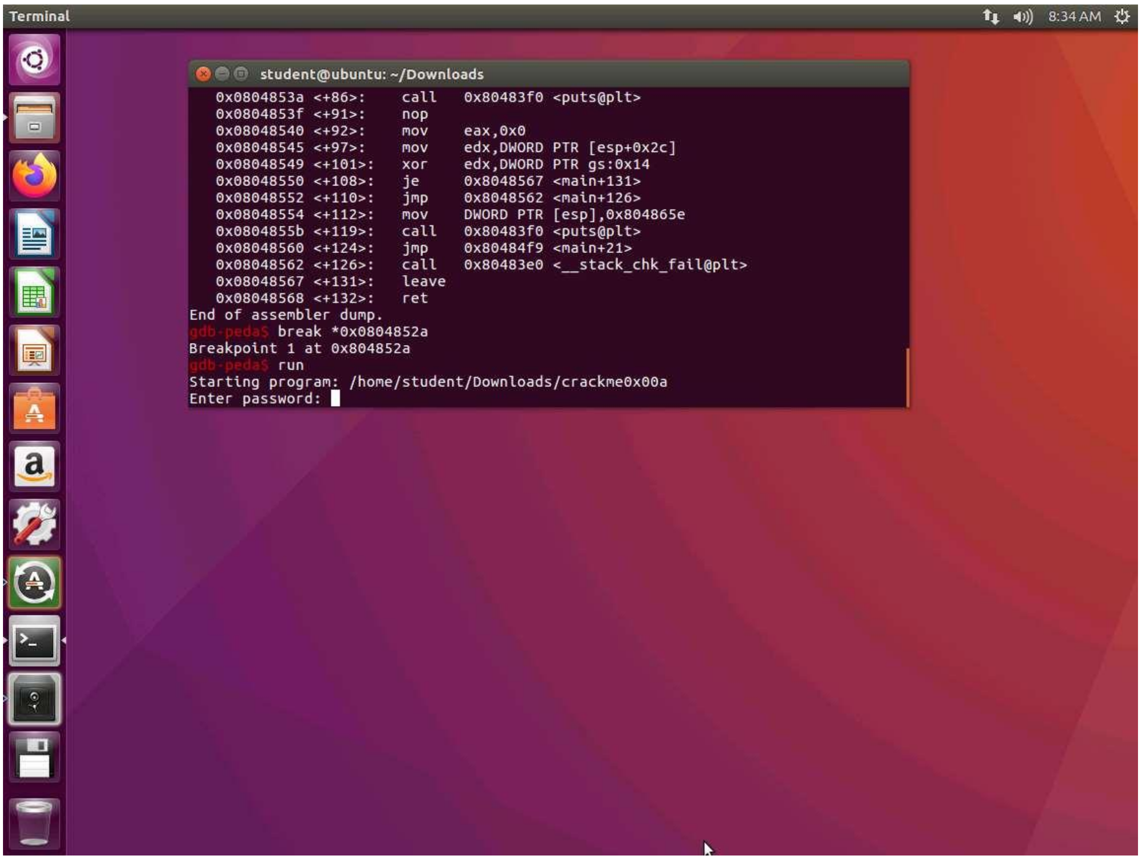


16. ☐ There is a strcmp instruction on <+70>.Therefore, let us set the breakpoint at the location and run the program using the following commands.

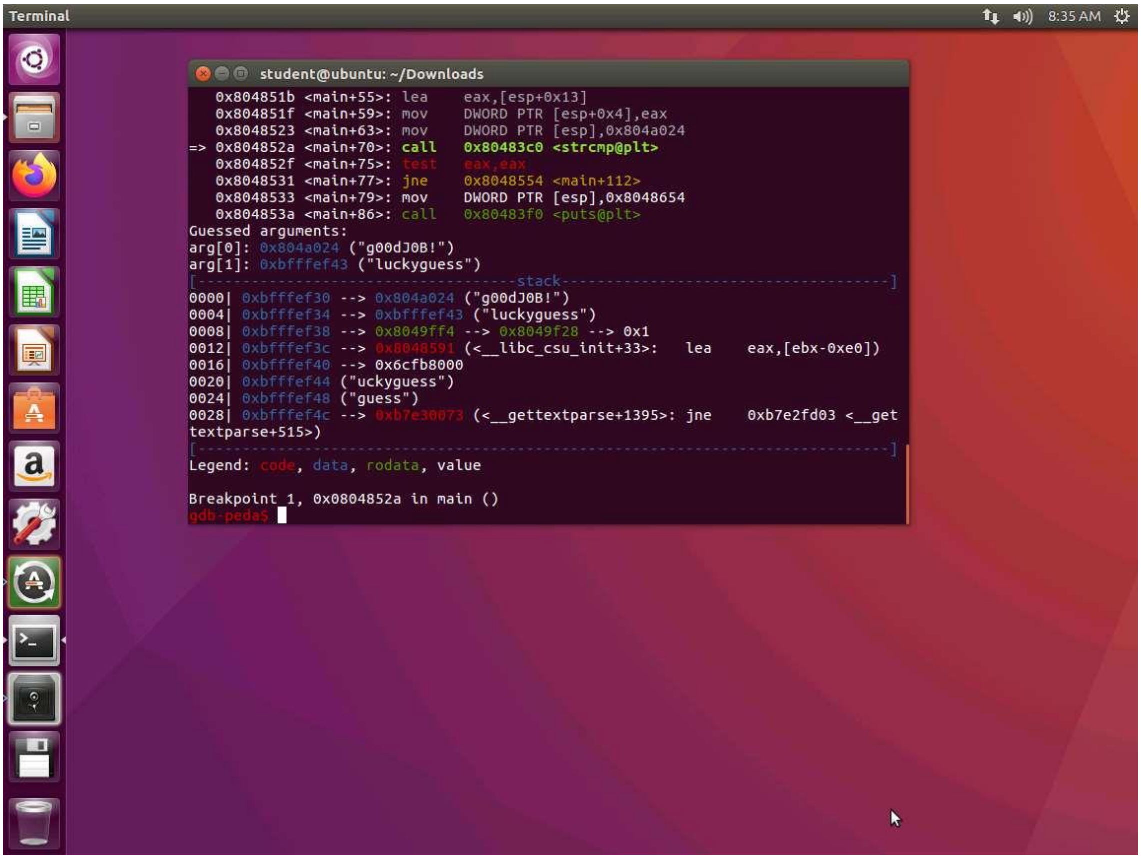
a. break *0x0804852a

b. run

17. ☐ The program will run until our breakpoint. An example of this is shown in the following screenshot.

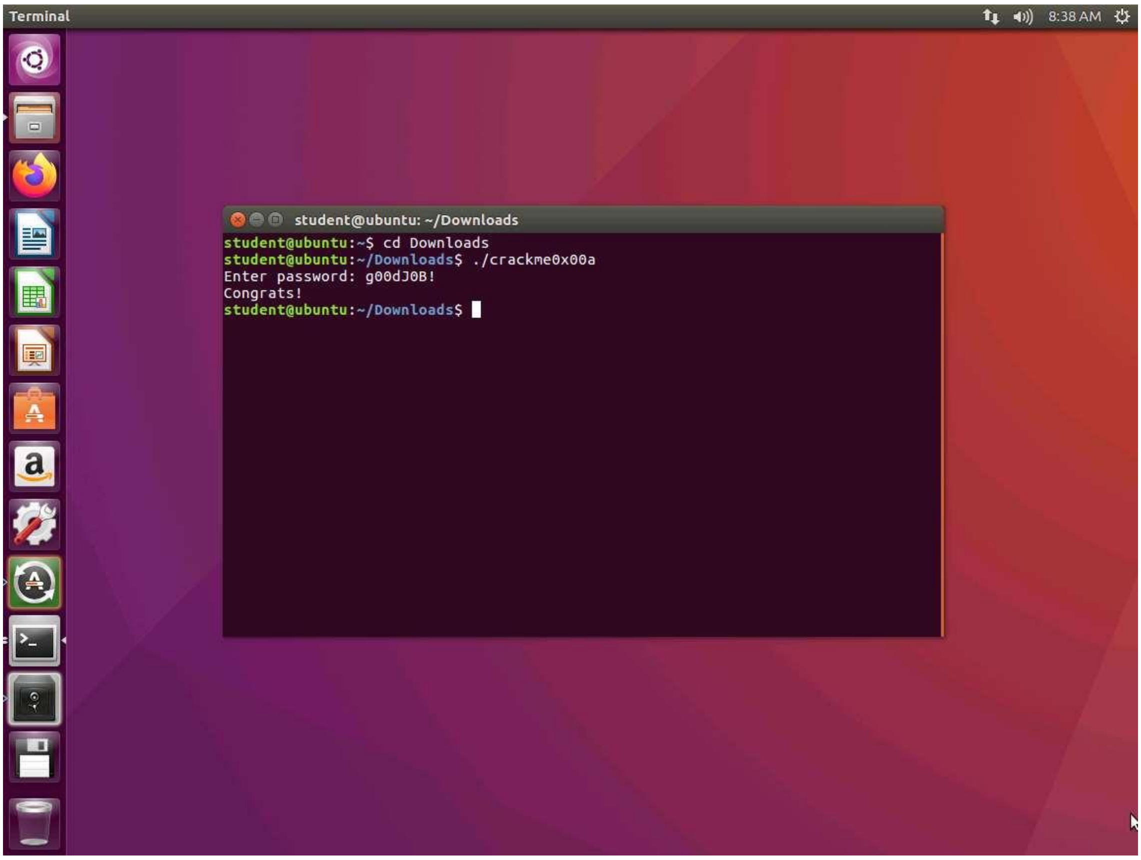


18. ☐ Enter the password **luckyguess**. The comparison will reference the actual password as shown in the following screenshot.



19. ☐ This is successful. To be certain, we need to test the discovered password.

Test the password to check whether it is correct, as shown in the following screenshot.

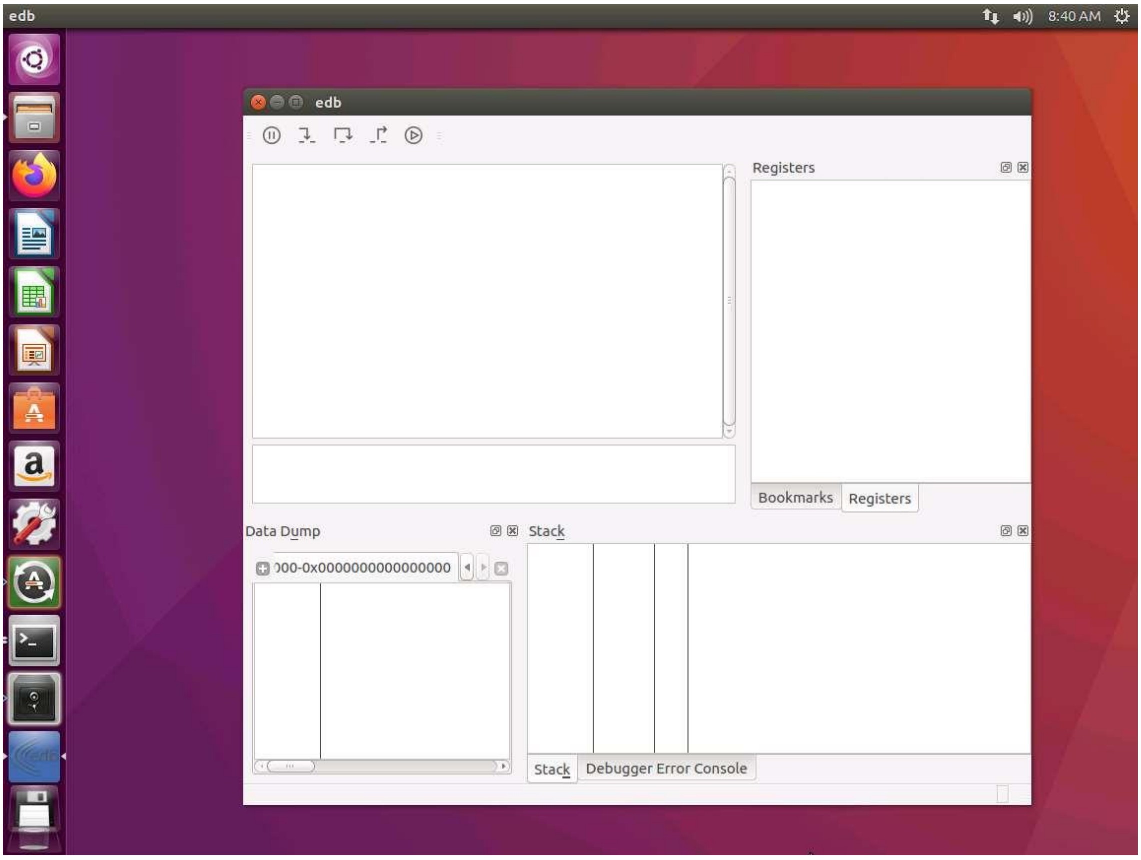


20. ☐ In computing, both hardware and software are reverse engineered.

However, in this case, we will only refer to reverse engineering software, which usually offers a compiled program that is already in its binary format. The source is not available, but we want to know how it was made, how it works, and how to change it as well.

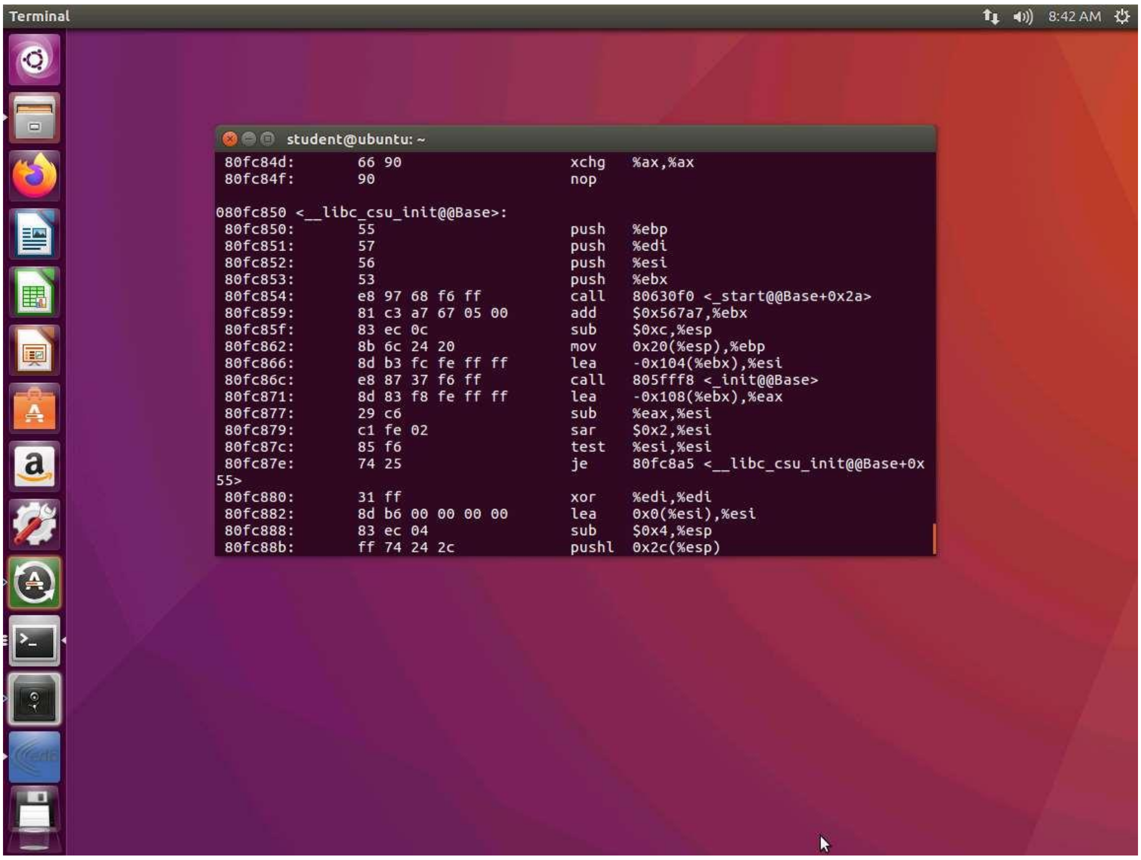
21. ☐ Now that we have performed the binary analysis of this file using these tools, let us move on and try some other techniques.

22. ☐ We want to look at another tool. Enter **edb**. An example of the output of this command is shown in the following screenshot.

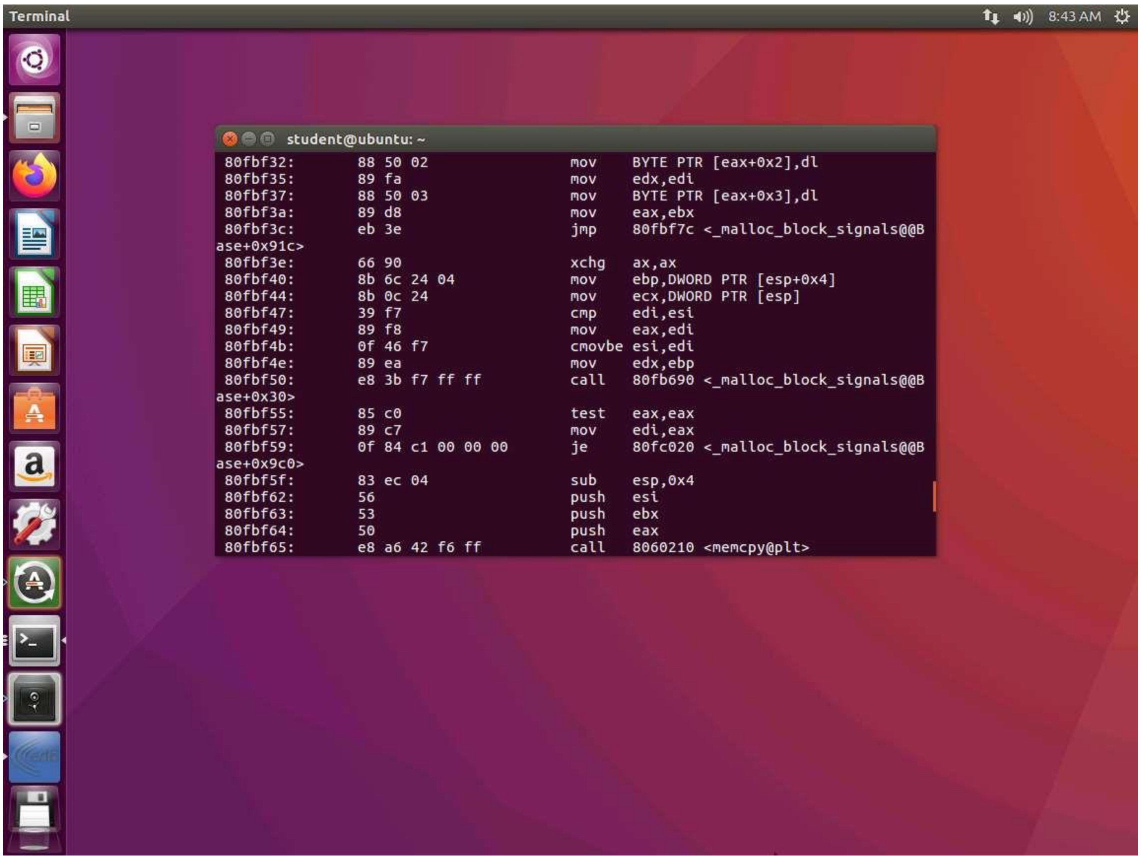


23. ☐ This is the dashboard for Evan's Debugger. We have discussed **edb** very briefly. You are encouraged to read more here: https://github.com/eteran/edb-debugger/wiki.

24. ☐ Let us now explore the 32-bit code and its components. In the 32-bit VM, enter **objdump -d /bin/bash**. An example of the output of this command is shown in the following screenshot.



25. ☐ Next, let us look at intel notation. In the terminal window, enter **objdump -d -M intel /bin/bash**. An example of part of the output is shown in the following screenshot.



26. ☐ Compare the above two screenshots. One thing that is different is the lack of a **%** in the intel format.

27. ☐ We used the objdump tool with different arguments in order to highlight the difference between the AT&T syntax and the Intel syntax for, in this case, the 32-bit version of Bash. The first command we issued used the **-d** command-line argument of objdump to disassemble the Bash binary. The output in the first screenshot shows, from left to right, the address of the instruction, the opcodes for the instruction and operands, the instruction itself, the source operand, a comma, and finally, the destination operand. In short, AT&T syntax is formatted as follows:

```
AT&T Syntax: <instruction> <source
operand>,<destination operand>
```

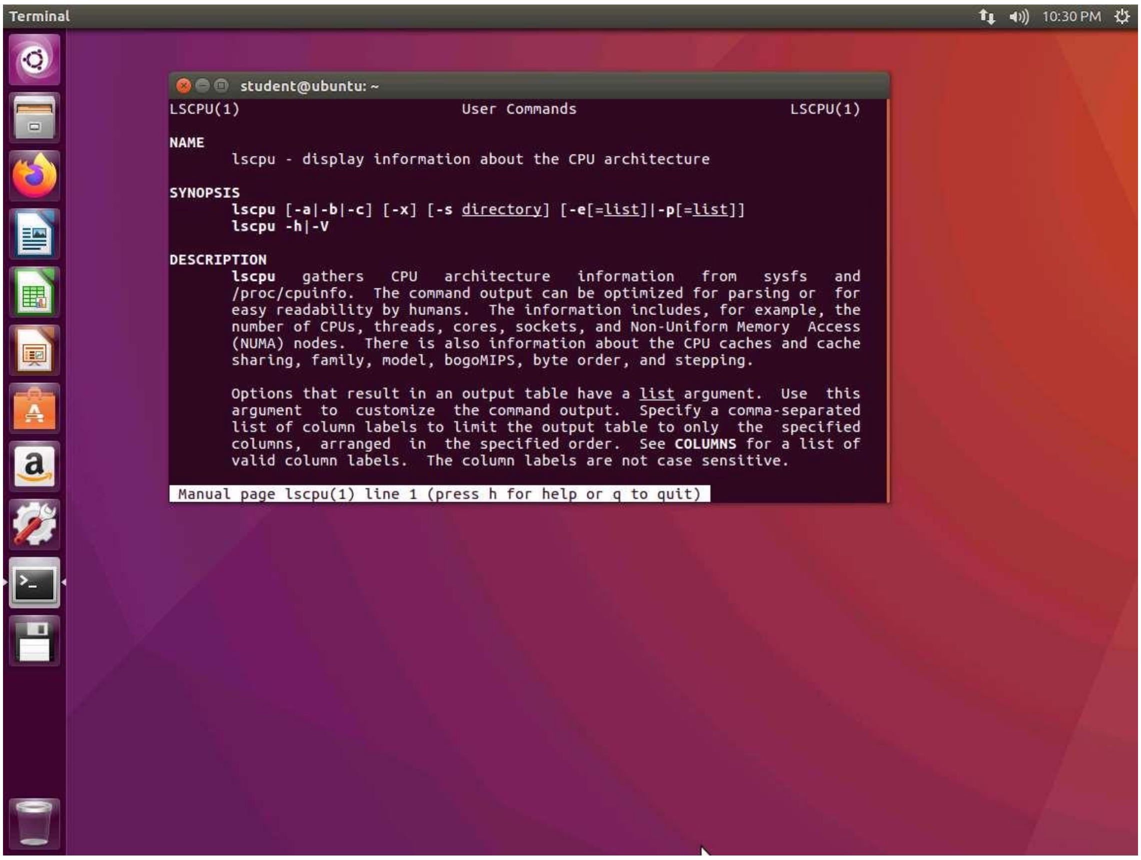
28. Then, we repeat the first command-line instruction but add the -M intel command-line argument, which tells the objdump tool to format the output using Intel syntax. The second screenshot is a truncated version of a much larger output and contains the same instructions as the first screenshot, except that it is formatted using the Intel syntax. Moving from left to right across the four columns, the first column shows the address in the memory of the instruction; the second column shows the opcodes for the instruction and operands; the third column shows the instruction itself; and the final column shows the destination operand, a comma, and the source operand. To summarize, the Intel syntax is formatted as follows:

```
Intel Syntax: <instruction> <destination
operand>,<source operand>
```

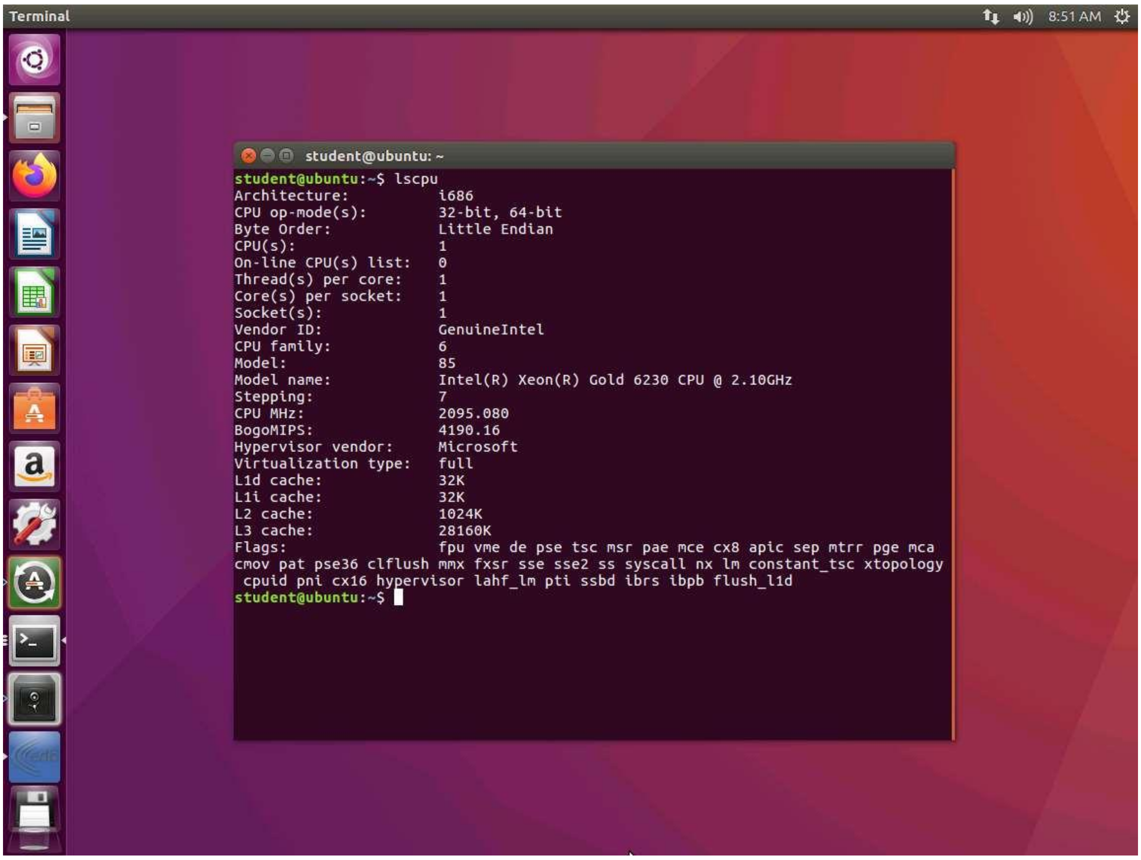
29. Fortunately, **nasm** will automatically understand which syntax we are using.

30. You may encounter several different naming conventions for 32-bit and 64-bit Intel assembly. When reading x86, x86-32, x86_32, IA32, and IA-32, know that this refers to 32-bit Intel assembly. x86-64, x86_64, IA64, and IA-64 refer to 64-bit Intel assembly. Intel, in this case, refers to the processor-specific instruction set, not necessarily the syntax format.

31. Let us now explore the different methods to extract information about the machine we are running. In the terminal window of the 32-bit virtual machine, enter **man lscpu**. Take a few minutes and review the information there.

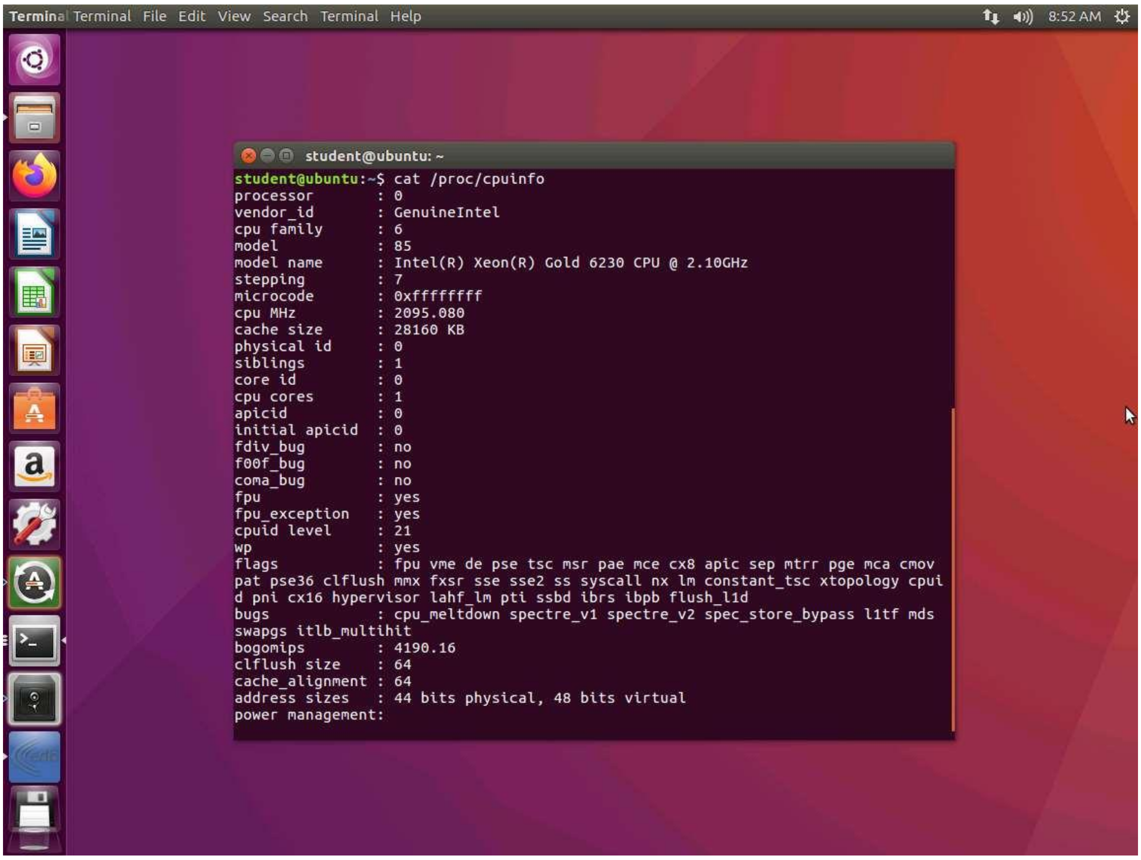


32. ☐ In the terminal window, enter **lscpu**. An example of the output of this command is shown in the following screenshot.



33. ☐ Now, let us look at **proc**. In the terminal window, enter **cat /proc/cpuinfo**.

The output of this command is shown in the following screenshot.



34. ☐ Now, let us use **gdb** to look at the registers. In the terminal window, enter the following commands:

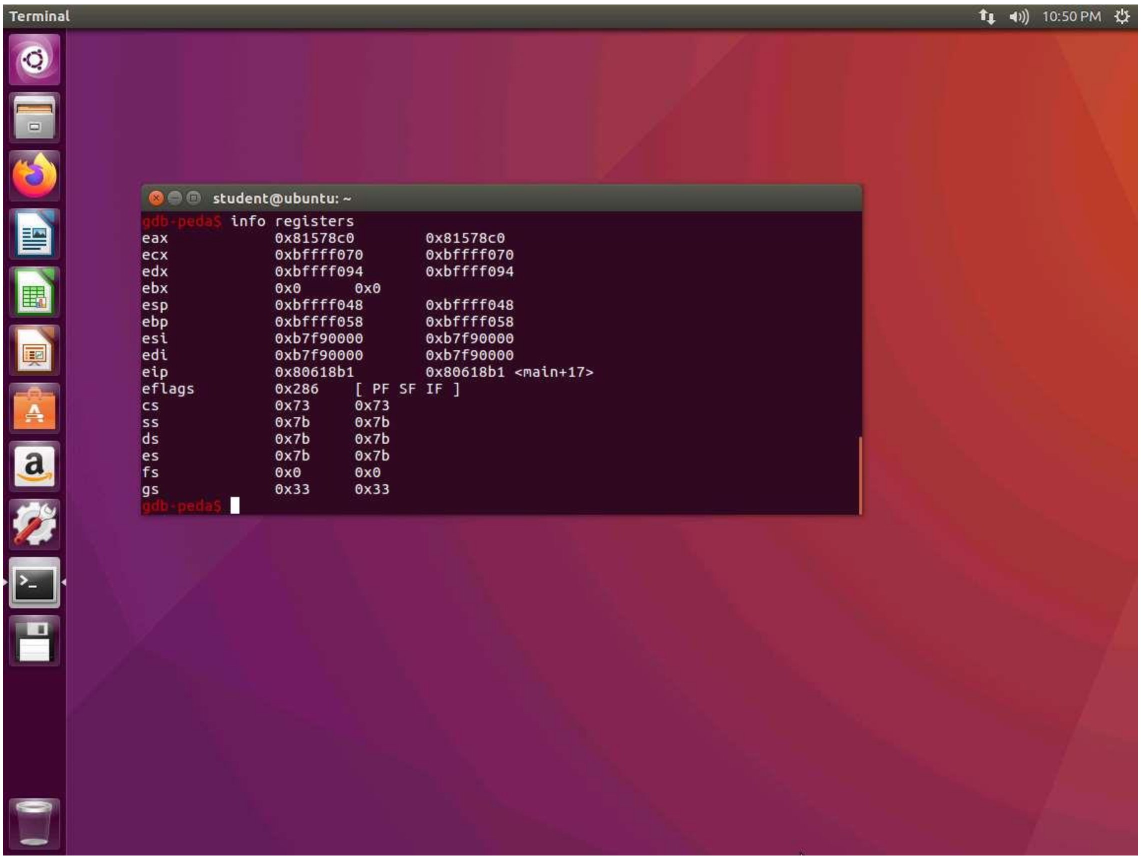
a. gdb -q /bin/bash

b. break main

c. run

d. info registers

An example of the output is shown in the following screenshot.

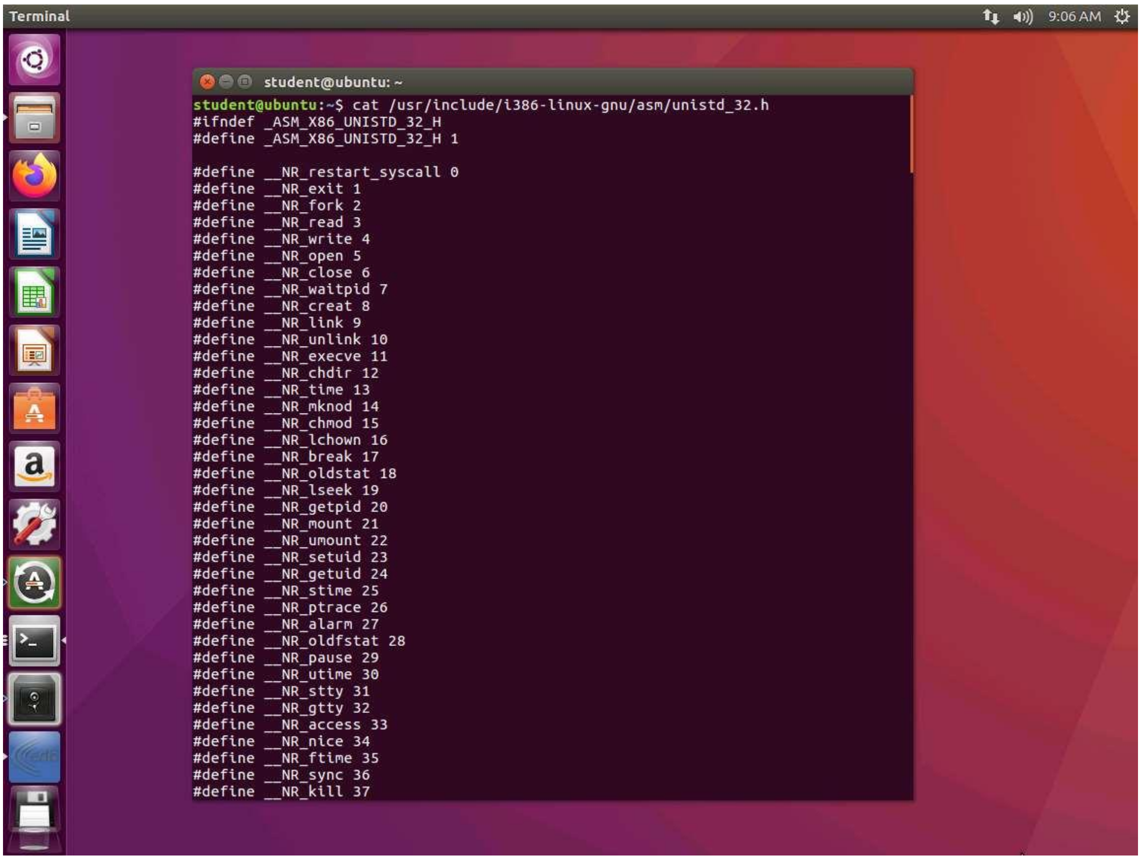


35. ☐ The important part of this output is the Endianness of our processor. Little-endian means that when we are reviewing or storing data in a register or on the stack, it must be formatted with the least significant byte first. Thus, 0x12345678 will actually look like 0x78563412. This is an extremely important concept to understand and a very important piece of information to know about our processor.

36. ☐ When we discuss assembly and processor architectures, it is important to understand Endianness. When the least significant bit appears in our output first, it is called a little-endian. When the least significant bit is last, we call that a nig-endian. Throughout this course, we will use little-endian to display the least significant bit first when storing data in memory. This essentially means that when we deal with strings or immediate values, we need to reverse the order of the bytes. Endianness is one area that usually causes confusion, because we often forget to take it into account when analyzing binaries.

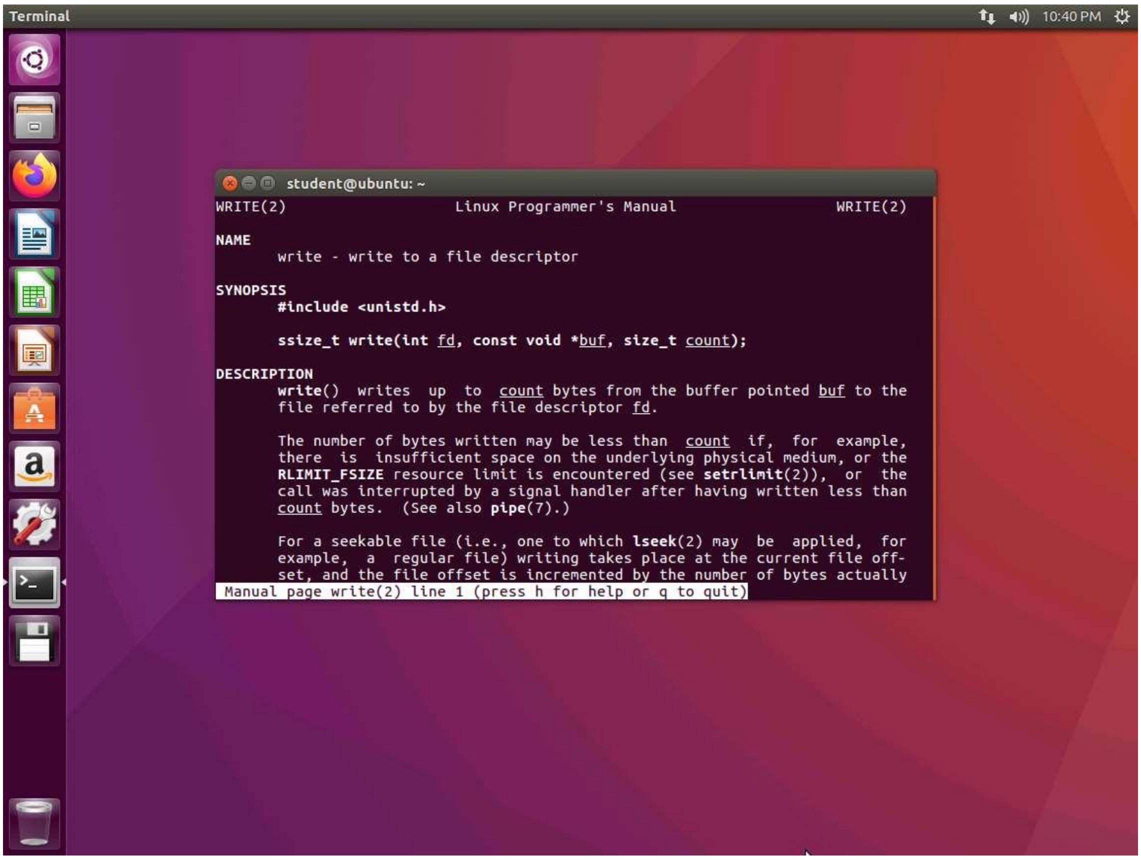
37. ☐ Enter **quit** to exit from gdb.

38. ☐ In the 32-bit machine, enter **cat /usr/include/i386-linux-gnu/asm/unistd_32.h**. An example of the output of this command is shown in the following screenshot.

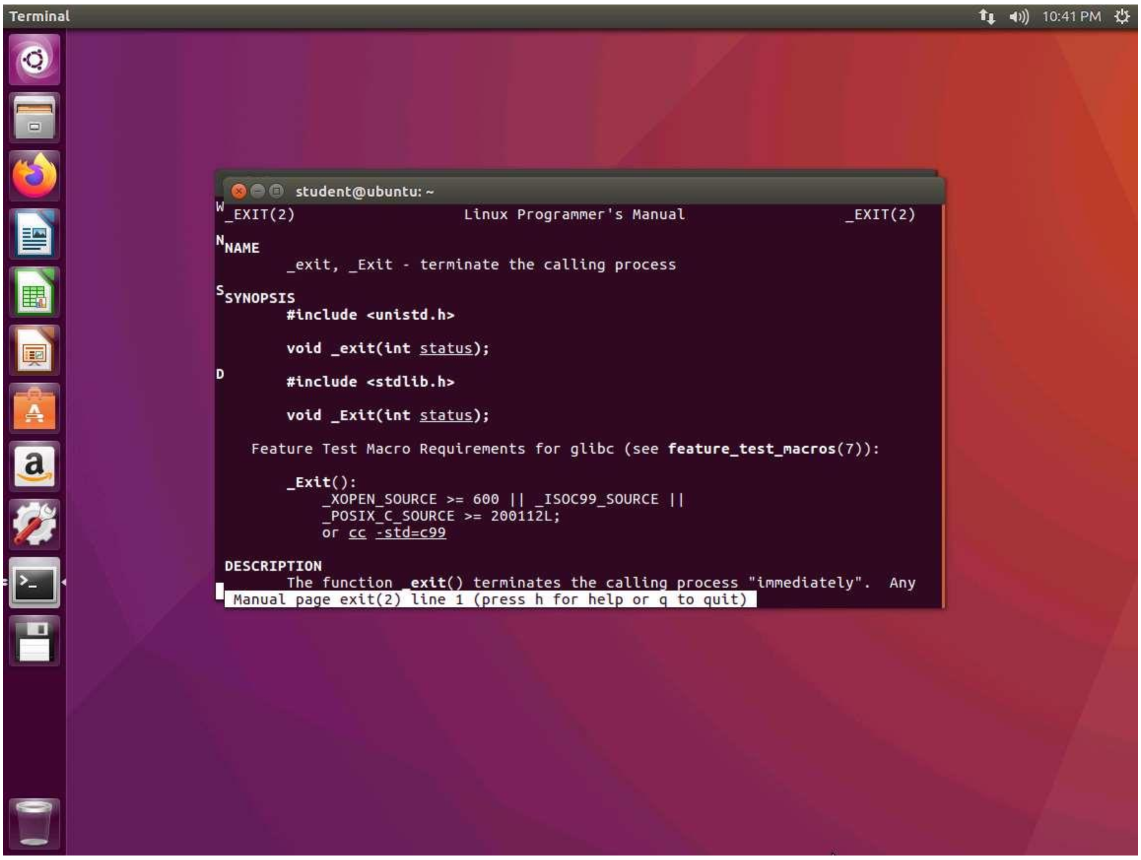


39. ☐ Open another terminal window using the shortcut SHIFT+CTRL+t.

40. ☐ In the terminal window, enter **man 2 write**. Take a few minutes and review the information in the man page.



41. ☐ Open another terminal window. Next, enter **man 2 exit**. Take a few minutes and review the information in the man page.



42. ☐ We are ready to create a small assembly program. Open a text editor of your choice and enter the following:

```
global _start

section .text

_start:
    ; write(int fd, const void *buf, size_t count)
    xor     eax,eax
    xor     ebx,ebx
    xor     ecx,ecx
    xor     edx,edx
    mov     al,0x4
    inc     bl
    push    0x000a2164
    push    0x6c726f57
```

```
        push    0x202c6f6c
        push    0x6c6548
        mov     ecx,esp
        mov     dl,0xf
    int     0x80
```

61. ☐ Save the files as **code-one.asm**, and ensure that the indentations are the same as in the example.

62. ☐ Next, enter the following commands:

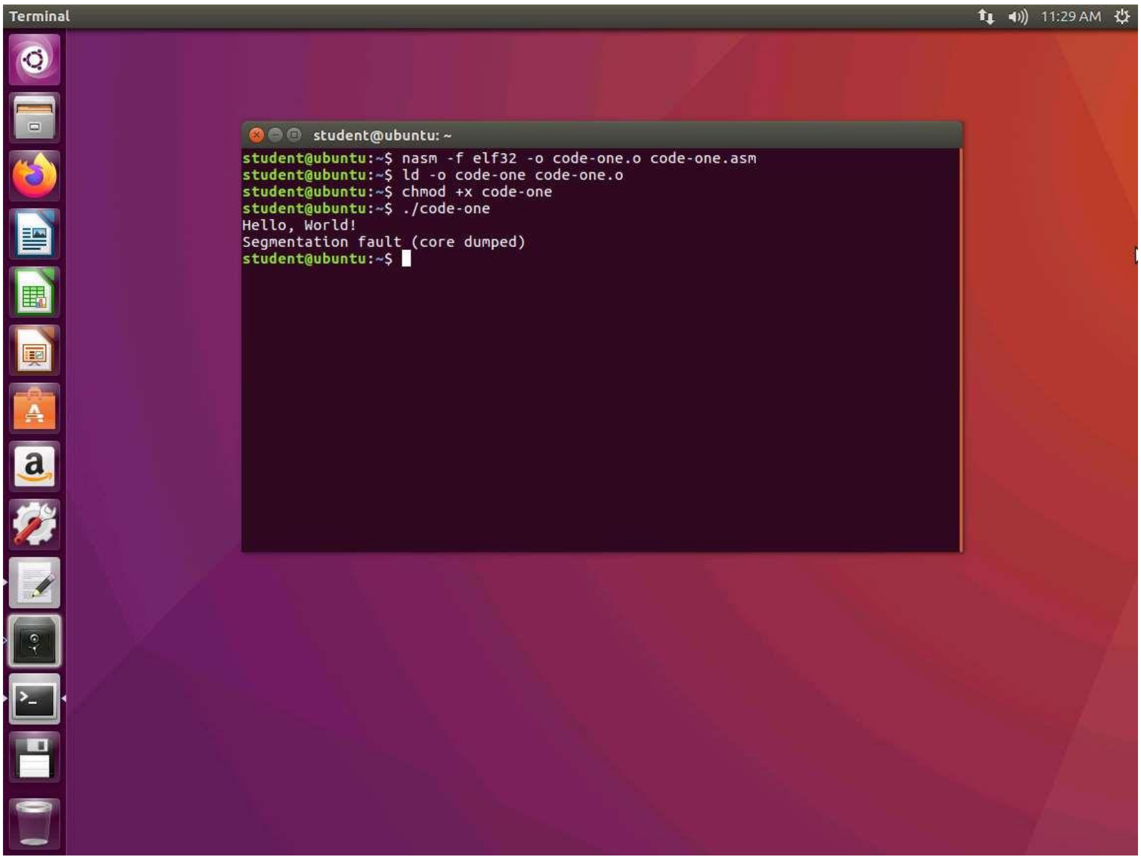
    a. nasm -f elf32 -o code-one.o code-one.asm

    b. ld -o code-one code-one.o

    c. chmod +x code-one

    d. ./code-one

63. ☐ An example output of this command is shown in the following screenshot.



64. ☐ As you see, it takes a lot of assembly to create a simple program, so this is one of the reasons why the C language is so popular.

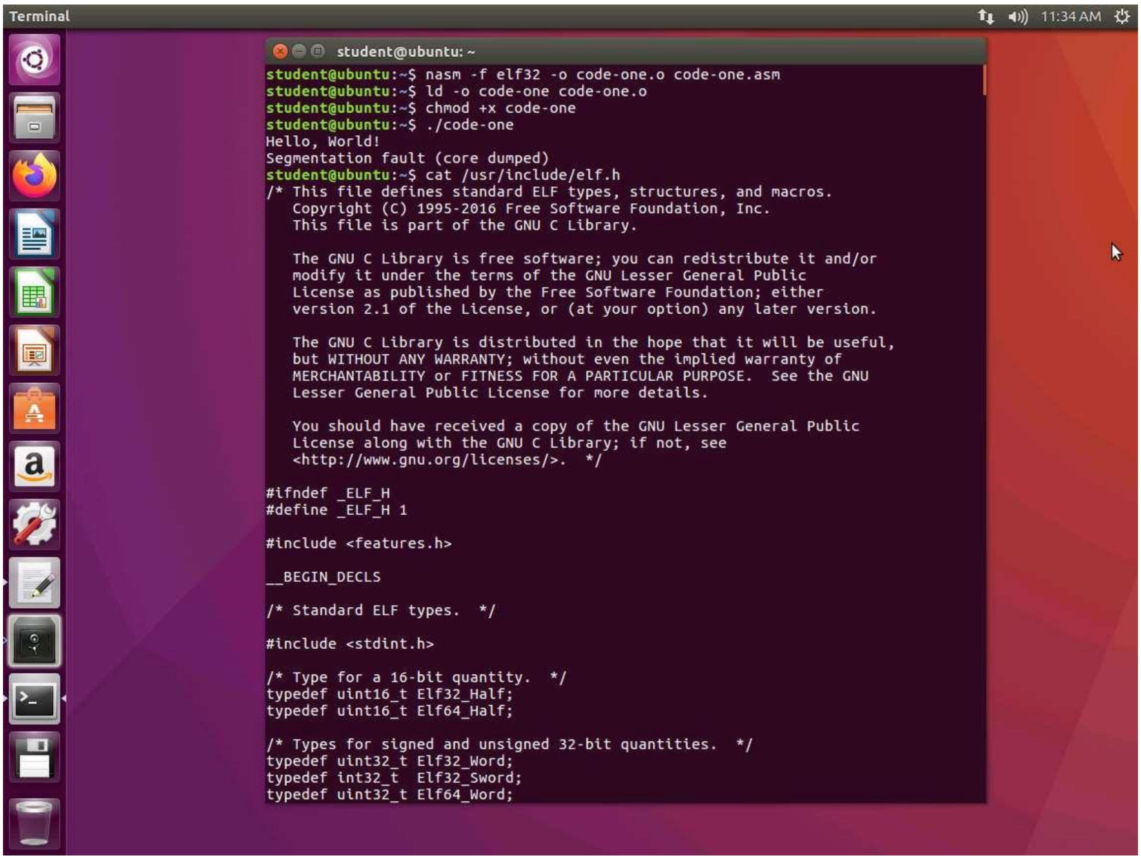
65. ☐ When reviewing disassembled binaries, we may see terms such as byte, word, double word, quad word, and double quad word. These terms represent 8 bits, 16 bits, 32 bits, 64 bits, and 128 bits, respectively.

66. ☐ When studying a disassembled binary's output, it is also important to understand how the width of the data within an operand may impact the instruction syntax. For example, **PUSH** may become **PUSH WORD** when pushing a 32-bit wide piece of data onto the stack.

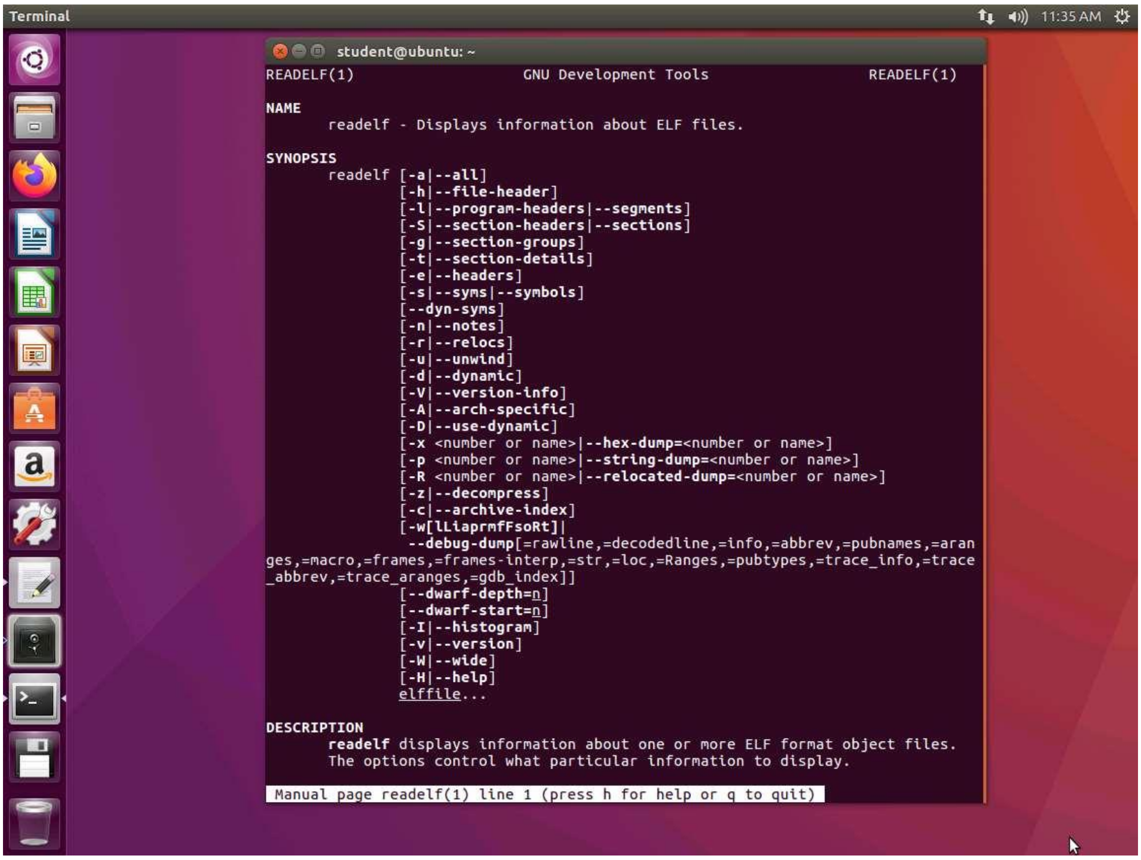
67. ☐ This program is based on the ELF-32 (executable and linking format). We will now extract information from the program so that we can understand it better.

68. ☐ As with anything, reading the man page is a good start. Enter **man elf**.

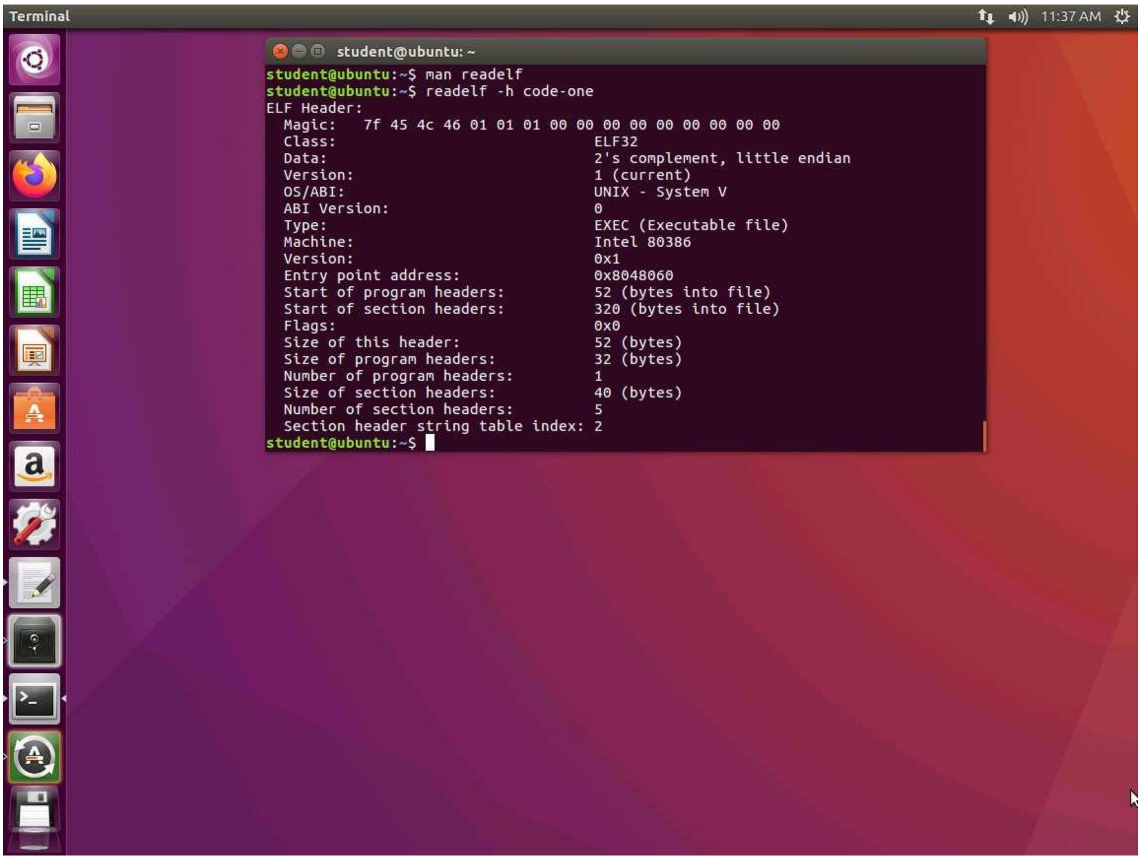
69. ☐ Take a few minutes and read the information contained within the man page. Once you have exited the man page, enter **cat /usr/include/elf.h**. The output of this command is shown in the following screenshot.



70. ☐ Now we are ready to learn more about **ELF** files. Enter **man readelf**. An example of the output of this command is shown in the following screenshot.

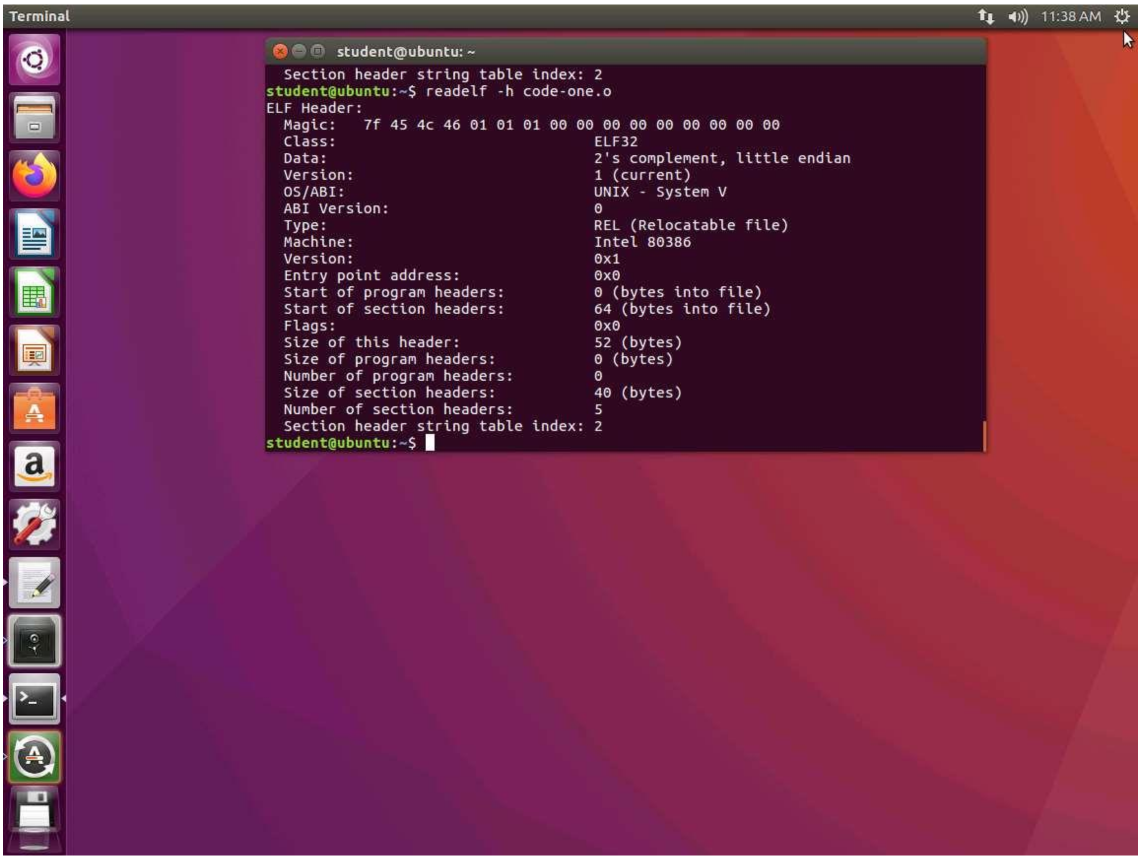


71. ☐ Next, let us review our code with this tool. Ensure that you are in the folder where you created your program, and enter **readelf -h code-one**. The output of this command, including the start with the ELF Header, is shown in the following screenshot.



72. ☐ The Magic is the **7f**, start of the ELF header and 45 (E), 4C(L) and 46(F). So, it starts with ELF. The next number **01** means we have 32 bytes. If we had 64, it would be a 02. Then, the next 01 is for little- endian and a value of 02 would be for big-endian.

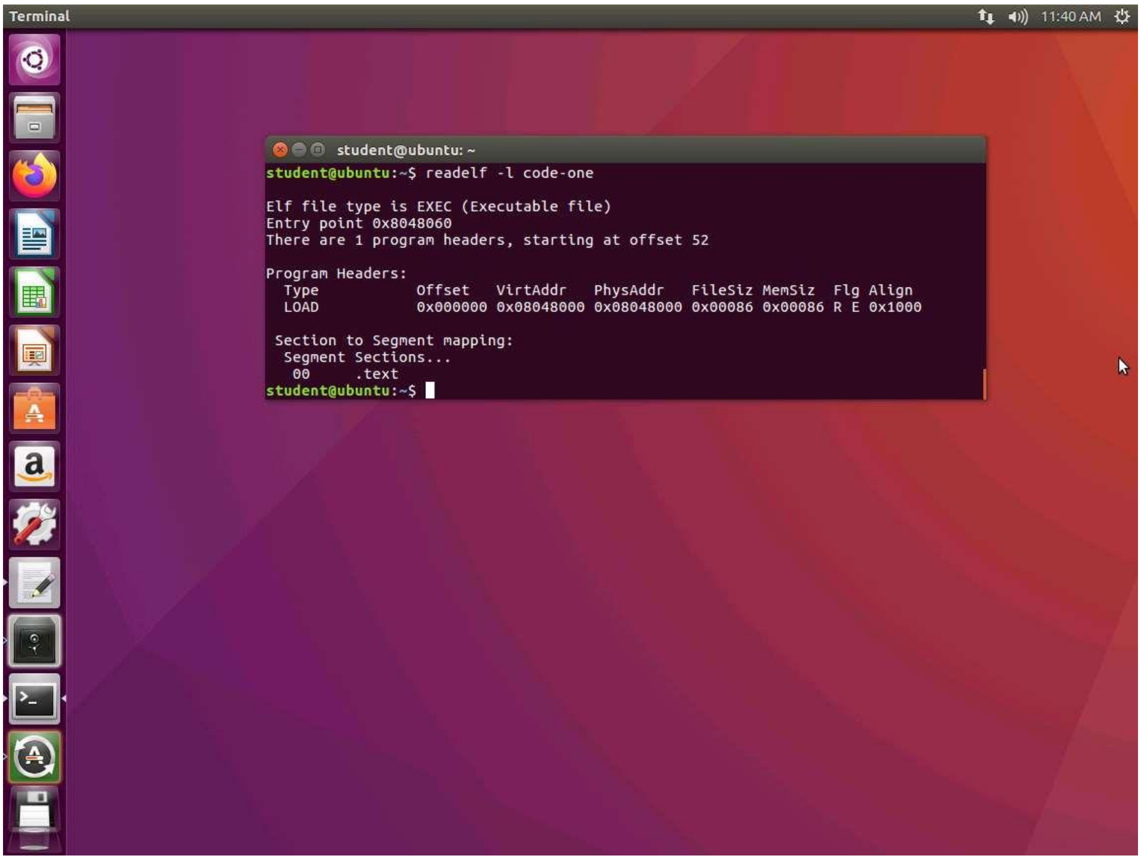
73. ☐ Next, we want to examine the object file. Enter **readelf -h code-one.o**. An example of the output of this command is shown in the following screenshot.



74. ☐ As we can see in the screenshot, Type is **REL**, so this is a relocatable file. As such, there are no program headers. The executable image program headers start 52 bytes in; there are none, so the start is 0.

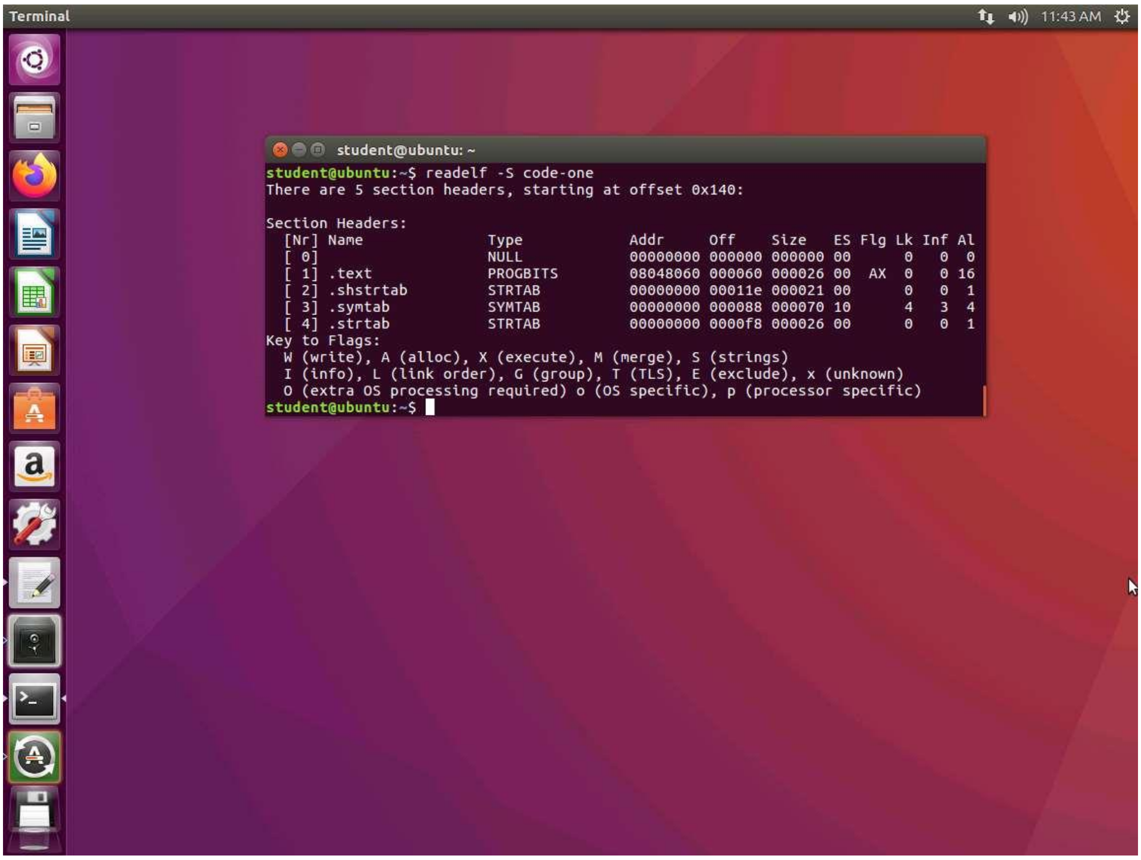
75. ☐ Next, we will look at the listing. Enter **readelf -l code-one** (that is a n "el").

An example of the output of this command is shown in the following screenshot.



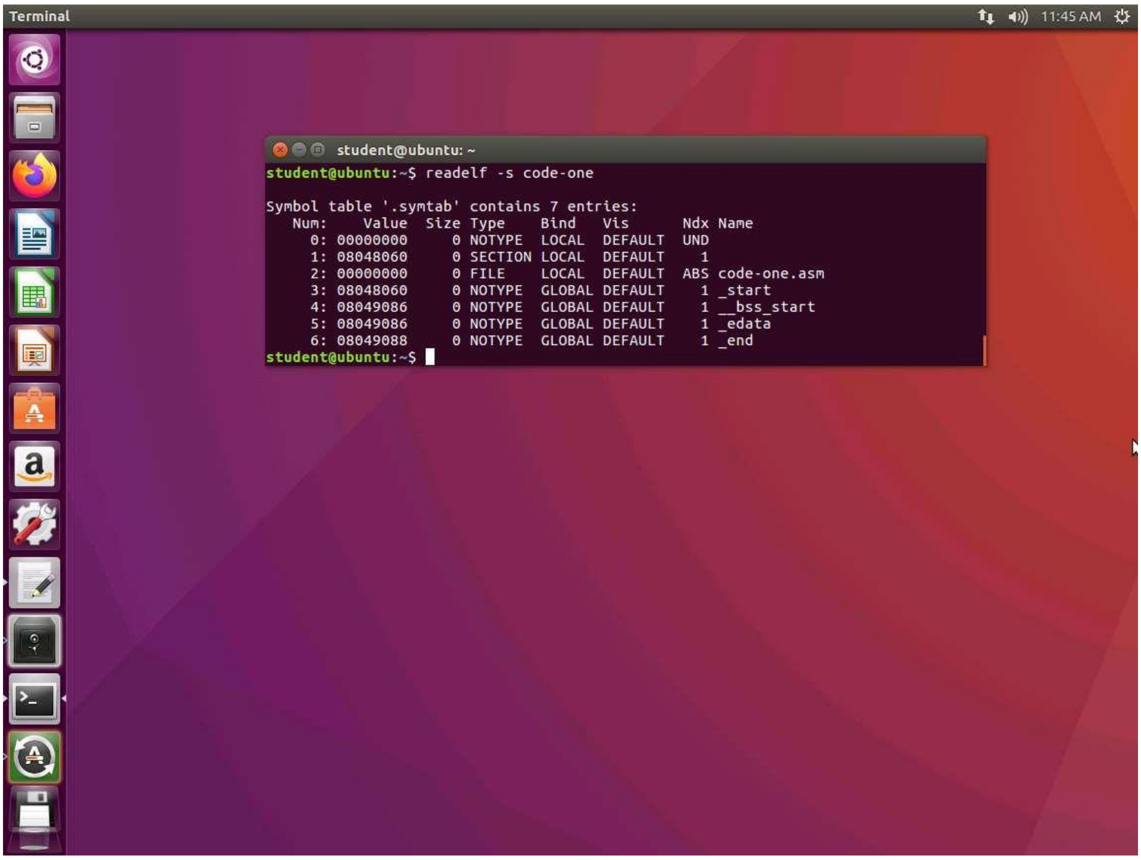
76. The program header is visible in the screenshot. It starts at virtual address 0x08048000, physical address 0x08048000, has a file size of 0x00086 (142) bytes, and takes up the same amount of memory. It is set with the R and E flags, indicating that segment is set with the permissions read/execute and requires a memory alignment of 0x1000 (4096) bytes. We can also see which sections are mapped to the segment, which is indicated in the program header table. This is the executable **.text** section.

77. Next, enter **readelf -S code-one**. An example of the output of this command is shown in the following screenshot.



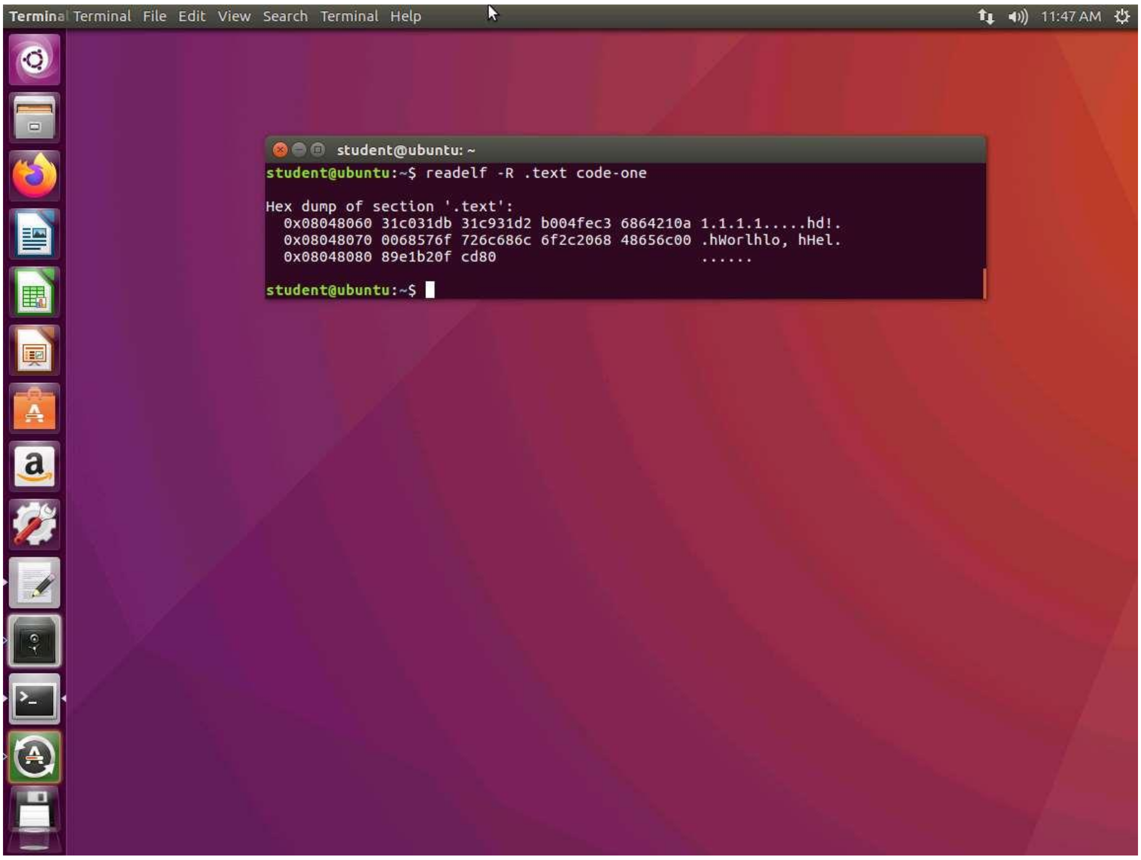
78. ☐ This screenshot shows the section headers. We can see that for the **.text** section, the type is indicated as **PROGBITS** and is marked as executable (**X**). The **PROGBITS** type indicates that this section contains program data. This is because we coded the program in the **.text** section.

79. ☐ Next, enter **readelf -s code-one**. An example of the output of this command is shown in the following screenshot.



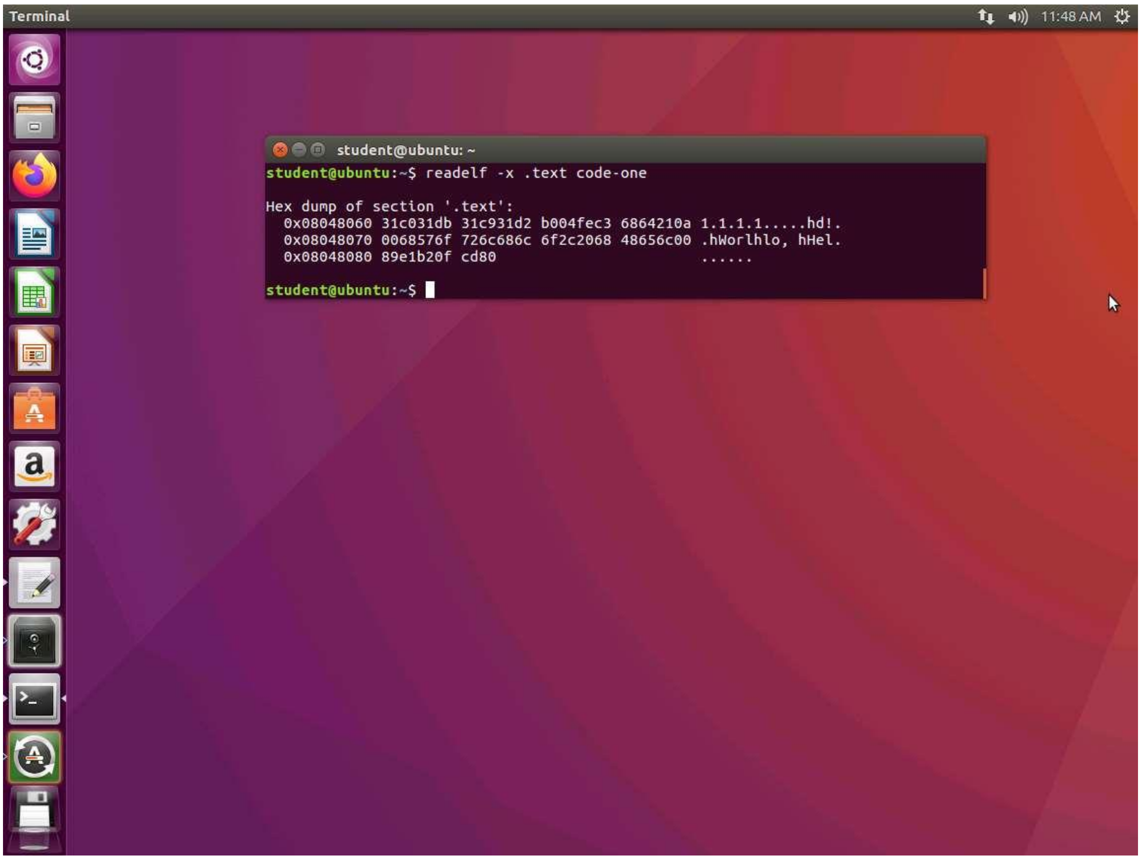
80. ☐ This screenshot shows the symbol table. We have the string table index, the memory location of the symbol itself, the size of the symbol is in bytes, the type of symbol, the symbol's binding, whether it is visible or not, the section index, and the symbol name. Notice that we recognize at least two entries in our output: the _start symbol, marked GLOBAL, and the name of our file.

81. ☐ Next, let us look at the **.text** info. Enter **readelf -R .text code-one**. An example of the output of this command is shown in the following screenshot.



82. ☐ This screenshot shows the relocated bytes.

83. ☐ Next, enter **readelf -x .text code-one**. The output is the same as the previous command, but this option dumps the hexadecimal.



84. ☐ The lab objectives have been achieved.