Worksheet 2 Solutions

1. `mov` vs `lea` - describe the difference between the following:

```
movq (%rdx), %rax
leaq (%rdx), %rax
```

movq takes the **contents** of what's stored in register %rdx and moves it to %rax. leaq computes the load effective **address** and stores it in %rax. leaq analogous to returning a pointer, whereas movq is analogous to returning a dereferenced pointer.

2.
(a) What would be the corresponding instruction to move 64 bits of data from register `%rax` to register `%rcx`?

```
movq %rax, %rcx
```

(b) What would be the corresponding instruction to move 64 bits of data from the memory location stored in register `%rax` to register `%rcx`?

```
movq (%rax), %rcx
```

3. Which of the functions `cool1, cool2, cool3` would compile into this assembly code?

```
       movl %esi, %eax
       cmpl %eax, %edi
       jge .L4
       movl %edi, %eax
.L4:
        ret
```

```
int cool1(int a, int b) {
      if ( b < a )
            return b;
      else
            return a;
}
```

```
int cool2(int a, int b) {
      if ( a < b )
            return a;
      else
            return b;
}
```

```
int cool3(int a, int b) {
      unsigned ub = (unsigned) b;
      if ( ub < a )
            return a;
      else
            return ub;
}
```

cool2

- Arguments passed to a function is stored in the %edi, %esi, etc registers
  - %edi is a and %esi is b
- When comparing, we compare as *cmp Two One*
  - Thus the instruction jge is checking if %edi is greater than or equal to %eax
  - This is essentially checking if a >= b, which is the else condition
- We can observe that when we do jump, %eax is not updated
  - We return b in the else case
- If we don't jump, we update %eax to %edi
  - We return a in the if case
- Thus cool2
- This question was inspired by a previous midterm

4. Operand Form Practice (see page 181 in textbook)

Assume the following values are stored in the indicated registers/memory addresses.

Address	Value	Register	Value
0x104	0x34	%rax	0x104
0x108	0xCC	%rcx	0x5
0x10C	0x19	%rdx	0x3
0x110	0x42	%rbx	0x4

Fill in the table for the indicated operands:

Operand	Value	Operand	Value
$0x110	0x110 (immediate value)	3(%rax, %rcx)	0x19 (value in %rax is 0x104, value in %rcx is 0x5, 3 + 0x104 + 0x5

			= 0x10C, value in 0x10C is 0x19)
%rax	0x104 (value stored in %rax)	256(, %rbx, 2)	0xCC (value in %rbx is 0x4, 256 in hex is 0x100, 0x100+(0x4 * 2) = 0x108, value in memory address 0x108 is 0xCC)
0x110	0x42 (value stored in memory address 0x110)	(%rax, %rbx, 2)	0x19 (value in %rax is 0x104, value in %rbx is 0x4, 0x104+(0x4*2) = 0x10C, value in memory address 0x10C is 0x19)
(%rax)	0x34 (%rax holds 0x104, memory address 0x104 holds 0x34)		
8(%rax)	0x19 (%rax holds 0x104, 8 + 0x104 = 0x10C, value in memory address 0x10C is 0x19)		
(%rax, %rbx)	0xCC (value in %rax is 0x104, value in %rbx is 0x4, 0x104 + 0x4 = 0x108, value in memory address 0x108 is 0xCC)		

- $ denotes immediates
- Note: any numbers starting with "0x" are hexadecimal numbers!!
- All of the operands can be evaluated using the specific formulas on page 181 in the textbook
- More generally, whenever you see an address of the form $D(r_b,r_i,s)$, where D is an number, r_b and r_i are registers, and s

is either 1,2,4, or 8, you can use the following formula:

$D + R[r_b] + R[r_i]*s$

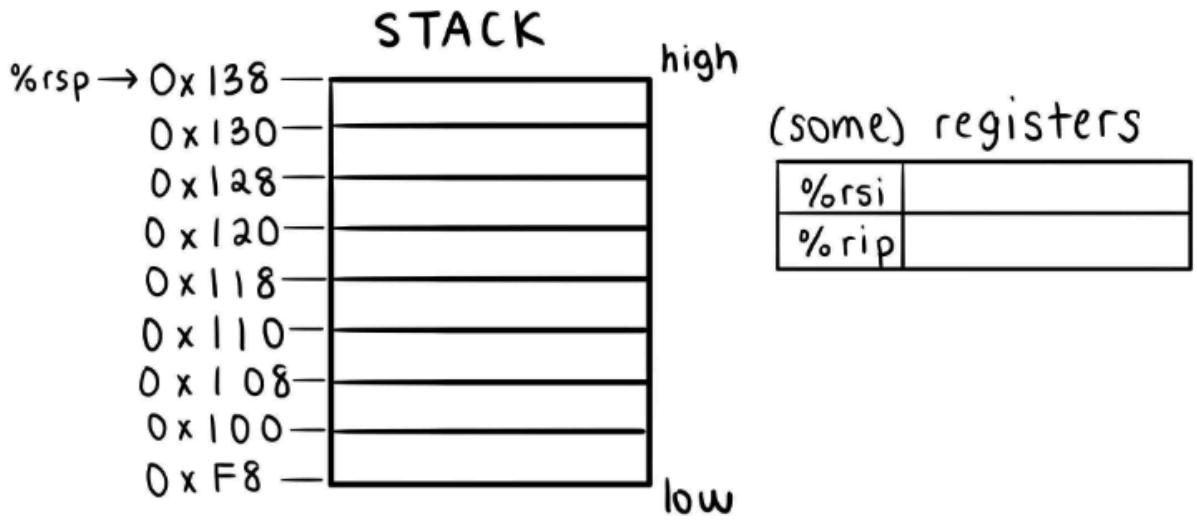
If D is missing, assume D == 0
If r_b is missing, assume r_b == 0
If r_s is missing, assume r_s == 1
If s is missing, assume s == 1

- For more practice, try practice problem 3.1 on page 182 of the textbook

5. Consider the following disassembled function:

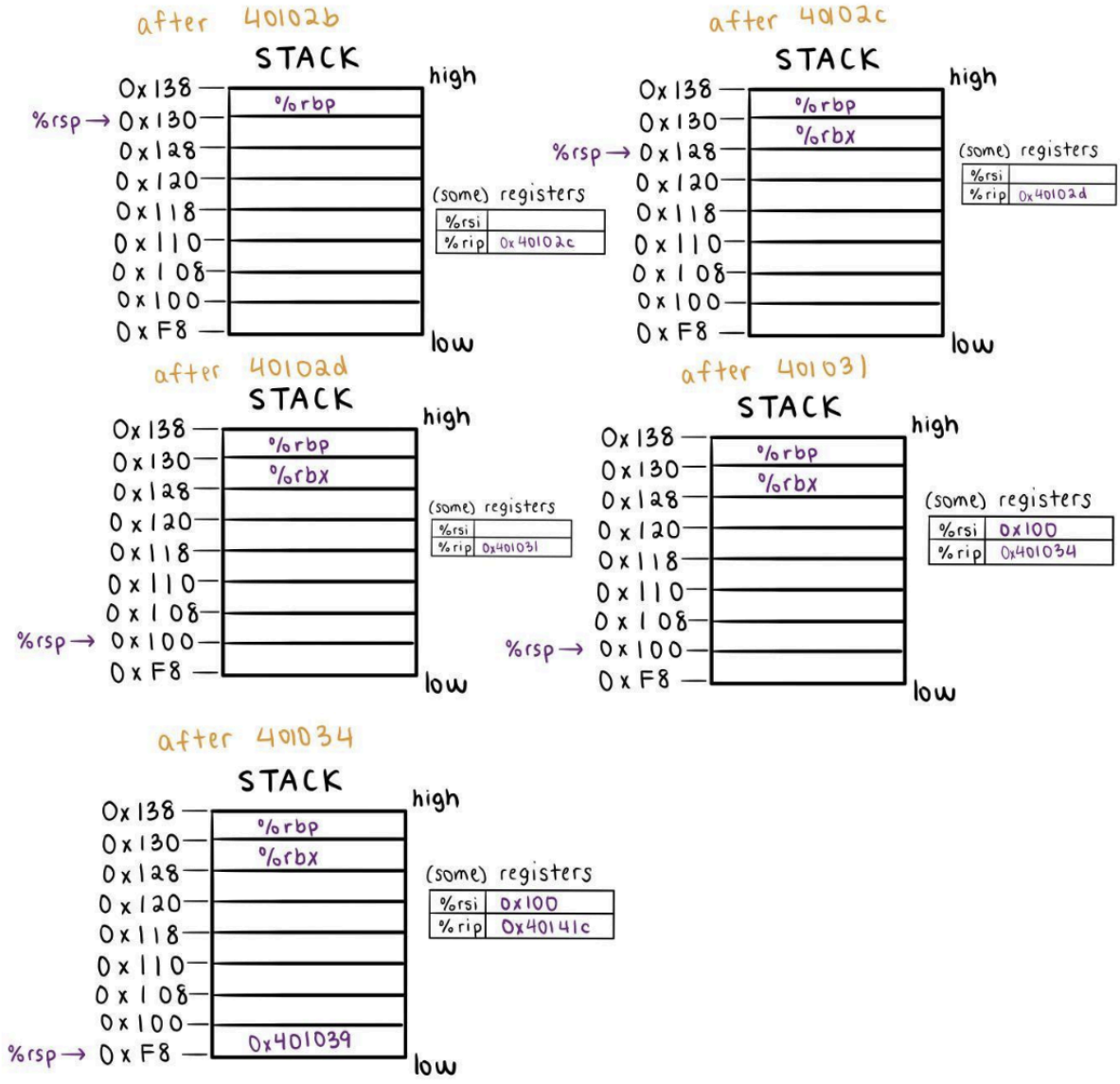
```
000000000040102b <phase_2>:
    40102b: 55                  push  %rbp
    40102c: 53                  push  %rbx
    40102d: 48 83 ec 28         sub   $0x28,%rsp
    401031: 48 89 e6            mov   %rsp,%rsi
    401034: e8 e3 03 00 00      callq      40141c <read_six_numbers>
    401039: 83 3c 24 01         cmpl  $0x1,(%rsp)
    …
```

(a) Assume %rsp initially has a value of 0x138. Draw the stack (see example diagram below) for the execution of <phase_2>, updating the stack and register values as necessary after each line is executed.



(b) Right after the callq instruction has been executed, what are the values of %rsp, %rsi, and %rip?7.

- Recall: pushing onto the stack DECREMENTS %rsp
- after 401034 (callq):
    - the return address (401039) gets pushed
    - %rip gets set to the callq address, %rip = 40141c
- Overall, after the callq insn the values are as follows:
    - %rsp = 0xF8
    - %rip = 40141c
    - %rsi = 0x100



Bonus Questions (not required)

6. Invalid `mov` instructions: explain why these instructions would not be found in an assembly program.

(a) `movl %eax, %rdx`
destination operand has the incorrect size

(b) `movb %di, 8(%rdx)`
mismatch between instruction suffix (b, 1 byte) and size of register %di (2 bytes)

(c) `movq (%rsi), 8(%rbp)`
source and destination for mov cannot both be memory references, i.e., cannot read and write to memory in the same instruction

(d) `movw $0xFF, (%eax)`
%eax (only 32 bits) cannot be used as an address register in x86-64

7. Condition codes and jumps: assume the addresses and registers are in the same state as in Problem 4. Does the following code result in a jump to `.L2`?

```
leaq (%rax, %rbx), %rdi
cmpq $0x100, %rdi
jg .L2
```

Yes.
1. First line will put 0x104 + 0x4 into %rdi
2. Second line sets condition codes according to 0x108 - 0x100, which sets no condition codes
3. Since jg is evaluated as ~(SF^OF)&(~ZF) which in this case is evaluates to 1, we will jump