Model 1 Low-Level Languages

The following program, shown in three different languages, calculates the sum of numbers from 1 to 10. In other words, it adds $1 + 2 + \ldots + 10 = 55$.

Machine Code
(1st Generation)

```
0x000:
0x000: 700001000000000000

0x100:
0x100:
0x100: 30f00b00000000000000
0x10a: 30f30100000000000000
0x114: 30f10200000000000000
0x11e: 30f20100000000000000

0x128: 2017
0x12a: 6107
0x12c: 734601000000000000

0x135:
0x135: 6013
0x137: 6021

0x139: 2017
0x13b: 6107
0x13d: 743501000000000000

0x146:
0x146: 00
```

Y86-64 Assembly
(2nd Generation)

```
.pos 0 code
    jmp _start

.pos 0x100 code
_start:
    irmovq  $0xb,  %rax
    irmovq  $0x1,  %rbx
    irmovq  $0x2,  %rcx
    irmovq  $0x1,  %rdx

    rrmovq  %rcx,  %rdi
    subq    %rax,  %rdi
    je      done

loop:
    addq    %rcx,  %rbx
    addq    %rdx,  %rcx

    rrmovq  %rcx,  %rdi
    subq    %rax,  %rdi
    jne     loop

done:
    halt
```

Standard C
(3rd Generation)

```
int main()
{
    int upper = 11;
    int sum = 1;
    int val = 2;


    while (val < upper)
    {
        sum = sum + val;
        val++;
    }
}
```

Questions (15 min)

Start time: ________

1. Compare the length of each program. Do not count labels (e.g, `0x000:`, `.pos 0 code`) or punctuation (e.g., {, }).

a) How many instructions of machine code? 14

b) How many instructions of assembly code? 14

c) How many non-blank, non-brace lines of C code? 7

2. All data values for this program are stored in registers named `%rax`, `%rbx`, etc.

a) In which register is the sum stored? %rbx

b) In which register is the next value to add stored? %rcx

3. The instruction irmovq means "move immediate value to register". Immediate values begin with a dollar sign ($), and registers begin with a percent sign (%).

a) What is the value 11 in assembly code? $0xb

b) Does assembly use decimal or hexadecimal? hexadecimal

c) Does Standard C use decimal or hexadecimal? decimal

4. In terms of the machine, what does an assignment statement do? As part of your answer, name the instructions in Model 1 that perform assignment.

Assignment updates the register (or memory location) that corresponds to the variable being assigned. In this program, the irmovq and addq perform assignment.

5. Consider the line "rrmovq %rcx, %rdi". The instruction rrmovq means "move (copy) register to register".

a) What is stored in register %rcx? The next value to be added

b) Where is this value copied to? Register %rdi

6. The instruction subq means "subtract". Given two registers R and T, subq performs $R - T$ and stores the result in T.

a) What is stored in register %rax? The value 11, which is the upper limit.

b) In what case would %rax − %rdi be zero? When their values are equal.

7. The instruction je means "jump if the last operation's result equals 0", and the instruction jne means "jump if the last operation's result does not equal 0". Circle the portion of assembly code that corresponds to the while loop in C.

Eight instructions should be circled, starting from the first rrmovq and ending with jne.