# CSCE-312 QUIZ 5 [24 POINTS]

**CSCE-312 | MONDAY APR 4, 2016**

**NAME:** SOLUTION **UIN:** ———

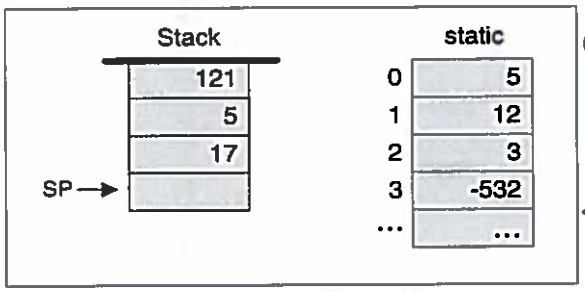
| Arithmetic / Boolean commands | Program flow commands |
|---|---|
| add | label (declaration) |
| sub | goto (label) |
| neg | if-goto (label) |
| eq | |
| gt | Function calling commands |
| lt | function (declaration) |
| and | call (a function) |
| or | return (from a function) |
| not | |
| Memory access commands | |
| pop x (pop into x, which is a variable) | |
| push y (y being a variable or a constant) | |

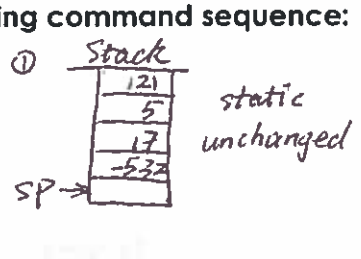
**Question 1. [3 points] Write pseudo VM code for the expression z = x+y using stack arithmetic. You may assume x, y, z are stored in consecutive memory locations. Pseudo VM code follows VM syntax as shown above but does not list specific memory segments like static, temp, argument, etc.**

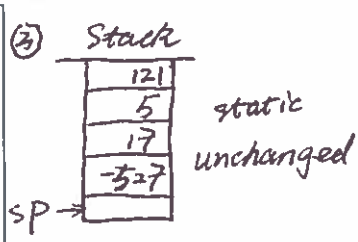
```
push x
push y
add
pop z
```

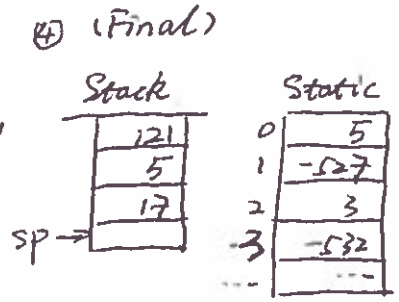
**Question 2. [4 points] For the picture below, draw the final picture of the stack and static segments after execution of the following command sequence:**

① push static 3
② push static 0
③ add
④ pop static 1




**Question 3. [9 points] Write pseudo VM code (stack arithmetic, memory, control, and functions) for the following high-level code. Assume that divide rounds down to an integer (for e.g. 8/3 returns 2). In your VM code you will need to write divide and multiply functions and call them from the main program.**

```
if (~ (a = 0))
        x = b/c
else
        x = b*c
```

```
push 0
push a
eq
if-goto else_part
push b
push c
call divide
pop x
goto endif
label else_part
 push b
 push c
 call multiply
 pop x
 label endif
```

```
divide (b, c)
 push 0
 pop res
 push b
 pop temp
label loop
 push c
 push temp
 lt
 if-goto end
 push res
 push 1
 add
 pop res
 push temp
 push c
 sub
 pop temp
 goto loop
label end
 push res
 return
```

```
multiply (b, c)
 push 0
 pop res
 push c
 pop temp
label loop
 push 0
 push temp
 eq
 if-goto end
 push res
 push b
 add
 pop res
 push temp
 push 1
 sub
 pop temp
 goto loop
label end
 push res
 return
```

Here is a reference for HACK assembly language syntax that we practiced in this course. All details are given below for references and then the questions follow.

- Two Instructions
  - A (Address): Fix the address on which to operate
  - C (Compute): Specify and Perform Operation
- CPU runs program that are resident in instruction memory (ROM)
- Registers and Memory Data are all 16 bits wide
- Addresses are 15 bits for both Instruction and Data Memory
  - ie. 32K words
- Memory is always accessed by referencing the contents of the A register
  - For example: D = M[516] -1 would imply setting A to 516 and then doing a read to memory location 516 via A and subtracting 1 from the read content to write the result to A

## A-Instruction

Syntax: `@value`

Where *value* is either:
- a non-negative decimal constant or
- a symbol referring to such a constant (later)

Semantics:
- Sets the A register to *value*
- Side effect: RAM[A] becomes the selected RAM register

Example: `@21`

Effect:
- Sets the A register to 21
- RAM[21] becomes the selected RAM register

Usage example:

```
// Set RAM[100] to -1
@100   // A=100
M=-1   // RAM[100]=-1
```

## C-Instruction in Entirety

Symbolic syntax: `dest = comp ; jump`

Binary syntax: `1 1 1 a c1 c2 c3 c4 c5 c6 d1 d2 d3 j1 j2 j3`

| comp | | c1 | c2 | c3 | c4 | c5 | c6 |
|---|---|---|---|---|---|---|---|
| 0 | | 1 | 0 | 1 | 0 | 1 | 0 |
| 1 | | 1 | 1 | 1 | 1 | 1 | 1 |
| -1 | | 1 | 1 | 1 | 0 | 1 | 0 |
| D | | 0 | 0 | 1 | 1 | 0 | 0 |
| A | M | 1 | 1 | 0 | 0 | 0 | 0 |
| !D | | 0 | 0 | 1 | 1 | 0 | 1 |
| !A | !M | 1 | 1 | 0 | 0 | 0 | 1 |
| -D | | 0 | 0 | 1 | 1 | 1 | 1 |
| A | -M | 1 | 1 | 0 | 0 | 1 | 1 |
| D+1 | | 0 | 1 | 1 | 1 | 1 | 1 |
| A+1 | M+1 | 1 | 1 | 0 | 1 | 1 | 1 |
| D-1 | | 0 | 0 | 1 | 1 | 1 | 0 |
| A-1 | M-1 | 1 | 1 | 0 | 0 | 1 | 0 |
| D+A | D+M | 0 | 0 | 0 | 0 | 1 | 0 |
| D-A | D-M | 0 | 1 | 0 | 0 | 1 | 1 |
| A-D | M-D | 0 | 0 | 0 | 1 | 1 | 1 |
| D&A | D&M | 0 | 0 | 0 | 0 | 0 | 0 |
| D\|A | D\|M | 0 | 1 | 0 | 1 | 0 | 1 |
| a=0 | a=1 | | | | | | |

| dest | d1 | d2 | d3 | effect: the value is stored in: |
|---|---|---|---|---|
| null | 0 | 0 | 0 | The value is not stored |
| M | 0 | 0 | 1 | RAM[A] |
| D | 0 | 1 | 0 | D register |
| MD | 0 | 1 | 1 | RAM[A] and D register |
| A | 1 | 0 | 0 | A register |
| AM | 1 | 0 | 1 | A register and RAM[A] |
| AD | 1 | 1 | 0 | A register and D register |
| AMD | 1 | 1 | 1 | A register, RAM[A], and D register |

| jump | j1 | j2 | j3 | effect: |
|---|---|---|---|---|
| null | 0 | 0 | 0 | no jump |
| JGT | 0 | 0 | 1 | if out > 0 jump |
| JEQ | 0 | 1 | 0 | if out = 0 jump |
| JGE | 0 | 1 | 1 | if out ≥ 0 jump |
| JLT | 1 | 0 | 0 | if out < 0 jump |
| JNE | 1 | 0 | 1 | if out ≠ 0 jump |
| JLE | 1 | 1 | 0 | if out ≤ 0 jump |
| JMP | 1 | 1 | 1 | Unconditional jump |

**Question 4. [8 points] Write HACK assembly code for the following VM commands:**

(1) ☐ **push constant 5**

(2) ☐ **sub**

(3) ☐ **pop local 2**

(4) ☐ **if-goto label (assume label is at ROM location 65)**

(1)
```
@5
D=A
@SP
A=M
M=D
@SP
M=M+1
```

(2)
```
@SP
AM=M-1
D=M
A=A-1
M=M-D
```

(3)
```
@2
D=A
@LCL
D=M+D
@temp
M=D
@SP
AM=M-1
D=M
@temp
A=M
M=D
```

(4)
```
@SP
AM=M-1
D=M
@65
D;JNE
```