This exam is a closed textbook and closed note exam. There are 5 big questions in this exam. You have 75 minutes to finish the questions. Please write your answers on separated pieces of paper. To avoid grading problems, please staple your solutions in the ascending order in the question number. All the questions in this exam are mandatory (no optional question).

Student ID (the last three digits): ___________________

**QUESTION #1 (10 minutes) – 20 points (4 points for each)**

(1) Given $N$ bits for 2’s complement integers, what is the largest positive integer (in decimal) a processor can have and what is the smallest negative integer (in decimal) a processor can have?

- The largest positive: $+2^{(N-1)} - 1$
- The smallest negative: $-2^{(N-1)}$

(2) Which of the following lw instructions is (are) not valid (the one that will cause error in PC-SPIM assembler) and why not for the one (ones) that is not valid?

(a) lw $v0, 89$
(b) lw $v0, ($a2)
(c) lw $s1, $s2$
(d) lw $a1, MY\_LABEL$ – assume that “MY\_LABEL” is properly defined somewhere in your assembly source code file.
(e) lw $v0, -812($a2)

**Solution:** (a) and (c)
What are the five different types of the numbers IEEE-754 floating-point numbers that can not be accurately represented by a processor?

Note: This question does not ask descriptions of the five different types of the numbers. Instead, it asks the name of the five different types of the numbers.

Solutions:

(a) Positive overflow
(b) Negative overflow
(c) Positive underflow
(d) Negative underflow
(e) Precision errors

“li $t0, (1024)” is an illegal instruction (if you try to assemble that instruction using PC-SPIM simulator, that instruction will cause a syntax error). What’s wrong?

The li instruction does not access the memory. Therefore, the second parameter “(1024)” means “the memory address of 1024” does not make sense to the li instruction.

We can fix the problem by replacing “li $t0, (1024)” by either “li $t0, 1024” or “lw $t0, (1024).”

Describe one major advantage and one major disadvantage for deepening a pipeline data path (e.g., increase ‘k’ from 5 to 20).

Advantage: the higher “speed up from its scalar counterpart will be achieved (for $k = 5$, the pipeline processor will be faster than its scalar counterpart by four times, while the speed up will be 20 times for $k = 20$).

Disadvantage: every time the deep pipeline data path hits data hazard or a control hazard the deep pipeline processor will be slowed down more than the shallow one will.
QUESTION #2 (15 minutes) – 20 points

Suppose that you wrote the following statements in C/C++;

```c
int my_int_01;
unsigned int my_int_02;

void main (void)
{
    my_int_02 = 46731;
    my_int_01 = my_int_02;
    printf("my integer: %d\n", my_int_01);
}
```

Assuming that the processor that runs this program is a 16-bit architecture processor (i.e., the registers and the ALU in the processor are all 16 bits), what number will you see? Note that “%d” in the `printf` statement means “print it as a decimal number”.

**Show all your work to find the number** (including your calculation)

QUESTION #3 (10 minutes) – 20 points

The program attached at the end of this exam (i.e., APPENDIX”) is the one for the multiplication of two numbers, each fits to 0-64. There are two errors in program control flow, either of which is not a syntax error. The system call numbers and the registers each system call used in the program are all correct. Find the errors and state your suggestion for how to fix them.

**Notes:**

- The only math instruction (mul) is correct in the program.
- The errors are not syntax errors (i.e., find errors that are not syntax errors)
- “bgt” means “branch if greater than” and the way the parameters are provided to all “bgt” instructions is correct in the program.
- “blt” means “branch if less than” and the way the parameters are provided to all “bgt” instructions is correct in the program.
- Everything before label “main” is correct.
QUESTION #4 (15 minutes) – 20 points

Our favorite program runs in (exactly) 9.56 seconds on processor A, which has a 2.1GHz clock (its clock cycle rate = 2.1GHz, 1G = 10^9). A processor designer is trying to build another processor, processor B, which will run this program in (exactly) 6.40 seconds. The designer has determined that processor will achieve the goal (i.e., run the program in 6.40 seconds) by a substantial increase in the clock rate. However, the substantial increase in the clock rate will affect the rest of the processor’s design, causing processor B to require 27% more clock cycles as processor A for this program.

What clock rate should we tell the designer target for processor B to run the program in 6.40 seconds?

*Show all your work.*

QUESTION #5 (15 minutes) – 20 points

What is the (interval) difference between the 59,038,368th and 59,038,369th smallest negative number in IEEE-754 floating-point fraction numbers (the one we discussed in the classroom)?

Show all your work for finding the answer for this question (90% of the credit goes to showing the correct process for finding the answer for this question).
APPENDIX (QUESTION #3)

```
# Multiplication.asm

.data
  STR_FIRSTNUM: .asciz "Enter the first number (0-64): ":
  STR_SECONDNUM: .asciz "Enter the second number (0-64): ":
  STR_WRONG: .asciz "Invalid input, keep integer in range 0-64."
  STR_LINE: .asciz "\n"
.text
.globl main

main:
  li $s0, 0
  li $s1, 64
LOOP:
  li $v0, 4
  la $a0, STR_FIRSTNUM
  syscall
  li $v0, 5
  syscall
  move $s2, $v0
  li $v0, 4
  la $a0, STR_LINE
  syscall
  bgt $s2, $s1, LOOP1
  bgt $s2, $s0, LOOP1
  LOOP1:
  li $v0, 4
  la $a0, STR_WRONG
  syscall
  li $v0, 4
  la $a0, STR_LINE
  syscall
  j LOOP
JUMP1:
  li $v0, 4
  la $a0, STR_SECONDNUM
  syscall
  li $v0, 5
  syscall
  move $s3, $v0
  li $v0, 4
  la $a0, STR_LINE
  syscall
  bgt $s3, $s1, LOOP2
  bgt $s3, $s0, LOOP2
  LOOP2:
  li $v0, 4
  la $a0, STR_WRONG
  syscall
  li $v0, 4
  la $a0, STR_LINE
  syscall
  j JUMP1
JUMP2:
  mul $a4, $s3, $s2
  li $v0, 1
  la $a0, ($s4)
  syscall
  jr $s1
# END OF THE LINE
```

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