Rose-Hulman Institute of Technology
Computer Science and Software Engineering
Profs. Archana Chidanandan and Larry Merkle

Exam 1

Name:_____

Instructions:

- Write all answers on these pages. Use the back as necessary.
- Clearly indicate your final answer.
- For full credit, show your work, and document your code.
- Read the entire examination before starting, and then budget your time.

Authorized resources:

- Green reference card from the text.

Unauthorized resources:

You are NOT permitted to use any resources other than those identified above. In particular, you may NOT use books, notes, electronic files, calculators, PDAs, or computers.

Good luck!

Problem Number	Maximum Points	Points Earned
1a	12	
1b	12	
1c	8	
1d	8	
2a	12	
2b	17	
3	16	
4	14	
Total	99 + 1 bonus	

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Problems

Problem 1a.[12 points] List the machine language fields and obtain the hexadecimal representation for the following MIPS instructions:

```
lw  $t0, 4($t1)
```

```
addi $s2, $s1, -5
```

```
sub  $t3, $t5, $a0
```

Problem 1b. [12 points]Give the MIPS assembly language statements represented by each of the following:

```
0x27a50004
```

```
0x001a2082
```

```
0x116a0004
```

Problem 1c. [8 points] Assume that the MIPS instruction

```
beq  $t0, $s0, Label
```

is located at address `0x0100 0040`, and that the 16-bit immediate field has the value

```
0000 0000 1000 0100
```

What is the 32-bit effective address value of `Label`? Express your answer in HEXADECIMAL. *Hint*: Remember that the offset is the signed number of instructions relative to the instruction FOLLOWING the branch.

Problem 1d - [8 points] Assume that the MIPS instruction `j Label` is located at address `0x8000 0000`, and `Label` is located at `0x8A00 0540`. What is the value of the 26-bit address field? Express your answer in BINARY.

Problem 2. You are designing an architecture with variable length instructions. Some instructions are 12 bits long, while others are 24 bits long. There are 8 general purpose registers and each of these registers is 12 bits wide. Addresses and immediates are also 12-bits wide. The instructions and their types are listed in the table below.

	Instruction	Type	Action	Length
1	Add rd, rs	A	Reg[rd] = Reg[rs] + Reg[rd]	12 bits
2	Sub rd, rs	A	Reg[rd] = Reg[rs] – Reg[rd]	12 bits
3	Jr rs	A	PC = Reg[rs]	12 bits
4	And rd, rs	A	Reg[rd] = Reg[rd] and Reg[rs]	12 bits
5	Or rd, rs	A	Reg[rd] = Reg[rs] or Reg[rd]	12 bits
6	Getinput rd, rs	A	Reg[rd] = SpecialRegister[rs]	12 bits
7.	Putoutput rd, rs	A	SpecialRegister[rd] = Reg[rs]	12 bits
8	Addi, rd, rs, 12-bit immediate	B	Reg[rd] = Reg[rs] + 12-bit immediate	24 bits
9	Beq rd, rs, 12-bit address	B	If (Reg[rs] = = reg[rd]) PC = 12-bit address	24 bits
10	Bne rd, rs, 12-bit address	B	If (Reg[rs] != Reg[rd]) PC = 12-bit address	24 bits
11	Lw rd, 12-bit address (rs)	B	Reg[rd] = Mem[Reg[rs] + 12-bit address]	24 bits
12	Sw rd, 12-bit address (rs)	B	Mem[Reg[rs] + 12-bit address] = Reg[rd]	24 bits

13	Sl rd, rs, 5-bit immediate	B	If(5-bit immediate > 0)
			Reg[rd] = Reg[rs] << 5-bit immediate
			else
			Reg[rd] = Reg[rs] >> 5-bit immediate
				24 bits

14	J 9-bit address	C	PC = PC[11:9] || 9-bit address	12 bits
15	Jal 9-bit address	C	PC = PC[11:9] || 9-bit address Reg[7] = PC	12 bits
16	Rfe	C	PC = EPC	12 bits

17	Slt rd, rs, rt	D	If(Reg[rs] < Reg[rt])
			Reg[rd] = 1;
			Else
			Reg[rd] = 0
				12-bits

a. [12 points] Show the instruction format for each type i.e. A, B, C, and D. Indicate clearly how many bits are allocated for each field. *Hint:* Start with the C and D types.

b. [17 points] For each of the instructions below, assign a value for the opcode field, as well as values for any fields that augment the opcode (e.g. the funct field for MIPS R-type instructions)

Instruction	Opcode	Values of fields that augment opcode
Add		
Sub		
Jr		
And		
Or		
Getinput		
Putoutput		
Addi		
Beq		
Bne		
Lw		
Sw		
Sl		
J		
Jal		
Rfe		
Slt		

Problem 3[16 pts] For each pseudoinstruction listed below, give a minimal sequence of actual MIPS instructions to accomplish the same thing. You may need to use `$at` for some of the sequences. "`big`" refers to a 32-bit immediate value and "`small`" refers to a 16-bit immediate value.

a. `move $sp, $s0`

b. `li $a0, big`

c. `lw $v0, big($k0)`

d. `ble $t8, $t9, label`

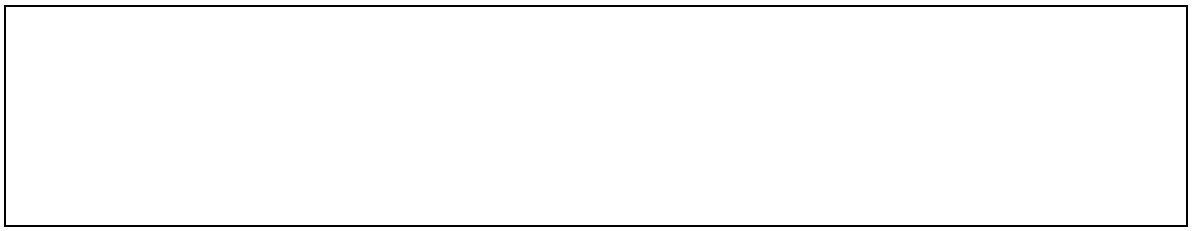
Problem 4 [14 pts] Complete the MIPS program on the following pages by filling in the provided spaces with MIPS assembly language statements such that:

- The procedure `dotProduct` accepts three input parameters: the addresses of two arrays and the size of the arrays.
- The procedure `dotProduct` returns the dot product of the vectors represented by the two arrays.
- The procedure `dotProduct` follows MIPS register usage conventions.
- The main program calls the procedure `dotProduct` in such a way that the dot product (0, 1, 2, 3, 4, 5, 6, 7, 8, 9) · (1, 2, 3, 4, 5, 6, 7, 8, 9, 10) = 0 + 2 + 6 + 12 + … + 90 = 330 is displayed.

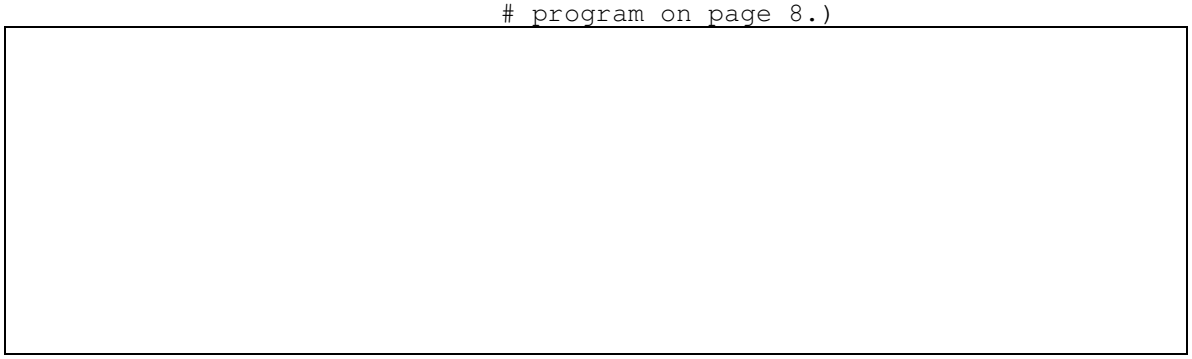
Assume the existence of another MIPS procedure `product` that returns in `$v0` the product of its two integer parameters, which are passed in `$a0` and `$a1`. In other words, even though `product` is not shown, you may call it, and you do not need to write it.

Read all the provided parts of the program, before you begin.

```
# Procedure dotProduct calculates and returns x (dot) y,
#  where the address of x, the address of y, and their
# (common) size are the three parameters of the procedure.
#
# A high-level language description of the procedure follows:
#
#        /**
#         * @param x  First array
#         * @param y Second array
#         * @param size  Number of elements in each array
#         * @return sum  The dot product
#         */
#        private static int dotProduct(
#                int[] x, int[] y, int size ) {
#           int sum = 0;
#           for( int count = 0; count < size; count++) {
#               sum = sum + product( x[ count ] , y[ count ] );
#           }
#           return sum;
#        }
#
# "Public" register usage:
#
#  $a0 - address of x
#  $a1 - address of y
#  $a2 - number of elements in each array
#  $v0 - x (dot) y
#
# "Private" register usage:
#
#  $s0 - address of x[ count ]
#  $s1 - address of y[ count ]
#  $s2 - size
#  $s3 - count
#  $s4 - sum
#
#  $t0 - flag
#
# Procedure entrance and initialization
#
dotProduct:
         addi     $sp, $sp, -16   # Create space on the stack

         sw       $ra, 0($sp)     # Place values to be preserved
         sw       $s0, 4($sp)     # on the stack.
         sw       $s1, 8($sp)
         sw       $s2, 12($sp)

                                  # Read input arguments from the
                                  # argument registers
         move     $s0, $a0        # $s0 = address of x[ count ]
         move     $s1, $a1        # $s1 = address of y[ count ]
         move     $s2, $a2        # $s2 = size

         move     $s3, $0         # count = 0
         move     $s4, $0         # sum = 0


loop:    slt      $t0, $s3, $s2   # if( count < size)
         beq      $t0, $0, exit1  # continue

         lw       $t1, 0($s0)     # Read x[ count ] from memory
         lw       $t2, 0($s1)     # Read y[ count ] from memory
                                  # Call "product" and pass
                                  # parameters
```



```
          add      $s4, $s4, $t3     # sum = sum +
                                     #       product (x[count],y[count])
          addi     $s0, $s0, 4       # $s0 = $s0 + 4
          addi     $s1, $s1, 4       # $s1 = $s1 + 4
          addi     $s3, $s3, 1       # count++

          j  loop
#
# Exit from dotProduct procedure
#
exit1:    move     $v0, $s4         # Move sum to the return value
                                    # register
          lw       $ra, 0($sp)      # Restore the values of the
          lw       $s0, 4($sp)      # preserved registers from the
          lw       $s1, 8($sp)      # stack.
          lw       $s2, 12($sp)
          addi     $sp, $sp, 16     # Restore the stack pointer

          jr $ra                    # Return to calling procedure
#
# Main program starts here
#
main:     la $s0, x              # x
          la $s1, y              # y
          la $s2, N              # size
          lw $s2, 0($s2)
                                 # Call “dotproduct” and pass
                                 # parameters (The registers to use
                                 # are listed at the beginning of the
                                 # program on page 8.)
```



```
          la $a0, Msg           # Print message
          li $v0, 4
          syscall

          move $a0, $s0        # Print the value of the value
                               # returned by the procedure “dotproduct”
          li $v0, 1
          syscall

          li $v0, 10            # Quit program
          syscall
```

The program continues on the next page

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```
#
# Sample data starts here
#
          .data
x:        .word 0 1 2 3 4 5 6 7 8 9
y:        .word 1 2 3 4 5 6 7 8 9 10
N:        .word 10
Msg:      .asciiz "The dot product is”
```