Instructions: This is a closed book, closed note exam. Calculators are not permitted. If you have a question, raise your hand and I will come to you. Please work the exam in pencil and do not separate the pages of the exam. For maximum credit, show your work.
Good Luck!

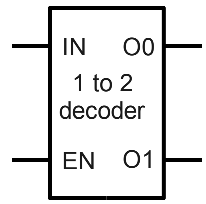
Your Name (***please print***) ____

1	2	3	4	5	total
24	30	25	36	30	145

Problem 1 (3 parts, 24 points) Decoding Decoders

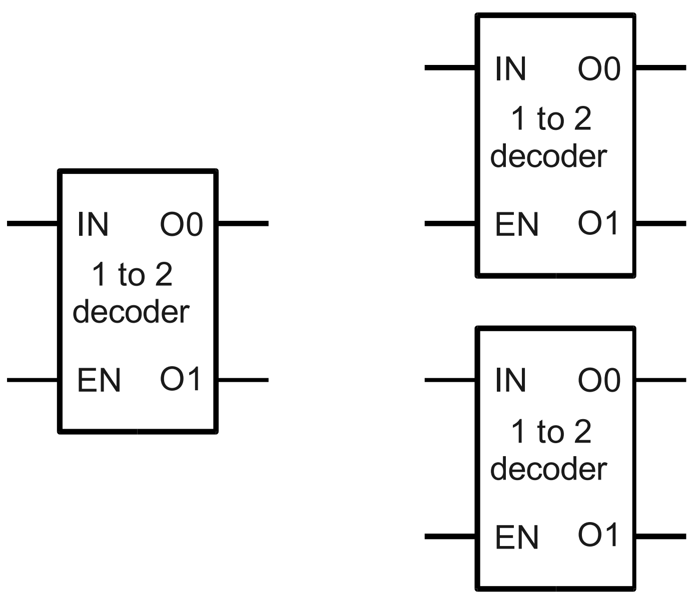
Part A (6 points) Define a 1 to 2 decoder by completing the behavior table.

IN	EN	O0	O1
X	0		
0	1		
1	1		



Part B (8 points) Implement a 1 to 2 decoder using basic gates. Assume only true (non-complemented) inputs are available. Label all inputs and outputs.

Part C (10 points) Using *only* the three 1 to 2 decoders shown below, implement a 2 to 4 decoder with an enable. Label the decoder inputs (IN_1, IN_0, EN) and outputs (O0, O1, O2, O3).



Problem 2 (4 parts, 30 points) Design Fiesta

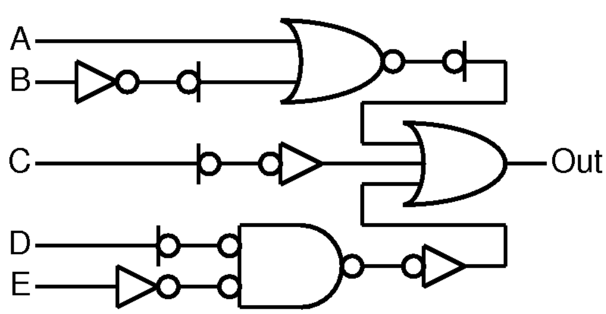
Complete each design below. Be sure to label all signals.

Part A: Implement the following expression using N and P type switches. $Out_X = (\overline{A} + B \cdot \overline{C}) \cdot D$

Part B: Implement the following behavior using only pass gates and inverters.

X	Y	Z	$\overline{Z}$
A	0	Q_o	$\overline{Q_o}$
A	1	A	$\overline{A}$

Part C: Determine the appropriate expression for this mixed logic design. How many transistors are required?



Out =

transistors =

Part D: Reimplement the design in Part D using *only* NAND and NOT gates. How many transistors are required?

transistors =

Problem 3 (1 part, 25 points) Assembly Programming

Part A (25 points) Complete this subroutine that searches an array of 100 integers beginning at memory address 5000 and returns its minimum ($4) and maximum ($5) values. Use the following registers: $1= array pointer, $2= end address, $3= current value, $6= branch predicate.

label	*instruction*	*comment*
MinMax:		**# init array ptr**
		# set end address
		# init min
		# init max
		# load current element
		# if current >= min
		# then skip update
		# update min
		# if current <= max
		# then skip update
		# update max
		# point to next element
		# if not done, loop
	jr $31	**# return to caller**

MIPS Instruction Set

instruction	example	meaning
add	`add $1,$2,$3`	`$1 = $2 + $3`
subtract	`sub $1,$2,$3`	`$1 = $2 - $3`
add immediate	`addi $1,$2,100`	`$1 = $2 + 100`
multiply	`mul $1,$2,$3`	`$1 = $2 * $3`
divide	`div $1,$2,$3`	`$1 = $2 / $3`
and	`and $1,$2,$3`	`$1 = $2 & $3`
or	`or $1,$2,$3`	`$1 = $2 | $3`
xor	`xor $1,$2,$3`	`$1 = $2 xor $3`
and immediate	`andi $1,$2,100`	`$1 = $2 & 100`
or immediate	`ori $1,$2,100`	`$1 = $2 | 100`
xor immediate	`xori $1,$2,100`	`$1 = $2 xor 100`
shift left logical	`sll $1,$2,5`	`$1 = $2 << 5 (logical)`
shift right logical	`srl $1,$2,5`	`$1 = $2 >> 5 (logical)`
shift left arithmetic	`sla $1,$2,5`	`$1 = $2 << 5 (arithmetic)`
shift right arithmetic	`sra $1,$2,5`	`$1 = $2 >> 5 (arithmetic)`
load word	`lw $1, ($2)`	`$1 = memory [$2]`
store word	`sw $1, ($2)`	`memory [$2] = $1`
load upper immediate	`lui $1,100`	$1 = 100 x 2^{16}$
branch if equal	`beq $1,$2,100`	`if ($1 = $2), PC = PC + 4 + (100*4)`
branch if not equal	`bne $1,$2,100`	`if ($1 ≠ $2), PC = PC + 4 + (100*4)`
set if less than	`slt $1, $2, $3`	`if ($2 < $3), $1 = 1 else $1 = 0`
set if less than immediate	`slti $1, $2, 100`	`if ($2 < 100), $1 = 1 else $1 = 0`
jump	`j 10000`	`PC = 10000`
jump register	`jr $31`	`PC = $31`
jump and link	`jal 10000`	`$31 = PC + 4; PC = 10000`

Problem 4 (4 parts, 36 points) "Math is fun"

Part A (9 points) Consider the instruction set architecture below with fields containing zeros.

0000 0000	00 0000	00 0000	00 0000 0000 0000 0000
opcode	dest. reg.	source 1 reg.	immediate value

What is the maximum number of opcodes? ______________

What is the number of registers? ______________

What is the range of the signed immediate value? ______________

Part B (9 points) For the eight bit representations below, determine the most positive value and the step size (difference between sequential values). **All answers should be expressed in decimal notation**. Fractions (e.g., 3/16ths) may be used. Signed representations are two's complement.

representation	most positive value	step size
unsigned integer (8 bits) . (0 bits)		
signed fixed-point (6 bits) . (2 bits)		
unsigned fixed-point (0 bits) . (8 bits)		

Part C (6 points) A 48 bit floating point representation has a 37 bit mantissa field, a 10 bit exponent field, and one sign bit.

What is the largest value that can be represented (closest to infinity)? 2 ______

What is the smallest value that can be represented (closest to zero)? 2 ______

How many decimal significant figures are supported? ______________

Part D (12 points) For each problem below, compute the operations using the rules of arithmetic, and indicate whether an overflow occurs assuming all numbers are expressed using a **five bit unsigned fixed-point** and **five bit two's complement fixed-point** representations.

	0.111 + 0.111	.0011 + 1.1101	1010.0 - 1001.1	0.00 - 100.00
result				
unsigned error?	□ no □ yes	□ no □ yes	□ no □ yes	□ no □ yes
signed error?	□ no □ yes	□ no □ yes	□ no □ yes	□ no □ yes

Problem 5 (5 parts, 30 points) Microcode in Reverse

The microcode fragment below comes from a color scanner control program that runs on the datapath discussed in class. Unfortunately, don't care values (X) have been converted to zeros. Assume register zero is a normal register (not hardwired to the value zero).

#	*X*	*Y*	*Z*	*rwe*	*im en*	*im va*	*au en*	*-a/s*	*lu en*	*lf*	*su en*	*st*	*ld en*	*st en*	*r/-w*	*msel*
1	0	0	3	1	1	4000	0	0	1	C	0	0	0	0	0	0
2	3	0	0	1	0	0	0	0	0	0	0	0	1	0	1	1
3	0	0	2	1	1	FF	0	0	1	8	0	0	0	0	0	0
4	0	0	0	1	1	8	0	0	0	0	1	0	0	0	0	0
5	0	0	1	1	1	FF	0	0	1	8	0	0	0	0	0	0
6	1	2	2	1	0	0	1	0	0	0	0	0	0	0	0	0
7	0	0	0	1	1	8	0	0	0	0	1	0	0	0	0	0
8	0	0	1	1	1	FF	0	0	1	8	0	0	0	0	0	0
9	1	2	2	1	0	0	1	0	0	0	0	0	0	0	0	0
10	0	0	0	1	1	8	0	0	0	0	1	0	0	0	0	0
11	0	2	2	1	0	0	1	0	0	0	0	0	0	0	0	0
12	2	0	2	1	1	2	0	0	0	0	1	1	0	0	0	0
13	3	2	0	0	0	0	0	0	0	0	0	0	0	1	0	1

Part A (5 points) Describe the operation that occurs during cycle 2. Be specific.

For the remaining parts, assume $0 = 0x44022118 at the end of cycle 2.

Part B (5 points) What is the value of register 0 at the completion of cycle 7 (in hexadecimal).

Part C (5 points) What is the value of register 2 at the completion of cycle 9 (in hexadecimal).

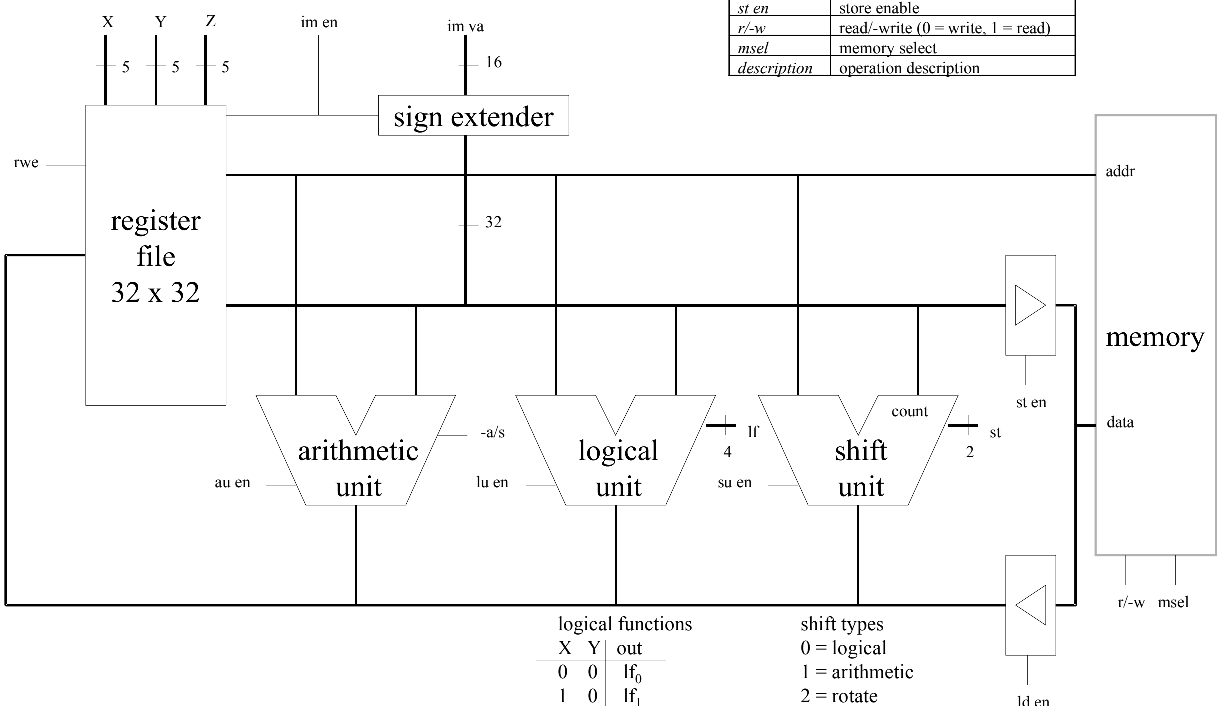
Part D (5 points) What is the value of register 2 at the completion of cycle 12 (in hexadecimal).

Part E (10 points) Describe the operation of this microcode fragment. Be specific.

---

cycle	cycle number
X	register driven onto X bus
Y	register driven onto Y bus
Z	register written from Z bus
rwe	register write enable
im en	immediate enable on Y bus
im va	immediate value

au en	arithmetic unit enable
-a/s	-add / sub (0 = add, 1 = subtract)
lu en	logical unit enable
lf	logical function
su en	shift unit enable
st	shift type
ld en	load enable
st en	store enable
r/-w	read/-write (0 = write, 1 = read)
msel	memory select
description	operation description



logical functions

X	Y	out
0	0	lf_0
1	0	lf_1
0	1	lf_2
1	1	lf_3

shift types
0 = logical
1 = arithmetic
2 = rotate
+ count shifts right
- count shifts left