This mock exam covers the material of the first half of the semester and consists of questions asked in the examination in 2019. Part II will be provided by the end of the semester.

Please show **all** your work. Answers without supporting work will not be given credit. Write answers in the spaces provided. Whenever you are required to write assembly code you may use **only** instructions from the supplied MIPS Instruction Reference. You have **30 minutes** to complete this mock exam. The maximum number of points in this part is **44** (the second part will have 56 points).

Name: _____ Student ID: _____

Exercise	1	2	3	4
Total	5	17	12	10
Mark				

1 Multiple-Choice Questions (5 Points)

Correct answer: +1 point, Wrong answer: -1 point, No answer: 0 points. Negative total points will be elevated to 0.

(a) `rs`, `rt` and `rd` use 5 bits which are enough to address all 32 registers.
◯ True ◯ False **Solution:** True

(b) The instructions `add`, `sub` and `or` are all of type R.
◯ True ◯ False **Solution:** True

(c) In a MIPS pipeline architecture, the execution time of a program is exactly equal to the number of instructions for a program times the clock cycle time.
◯ True ◯ False **Solution:** False

(d) CISC instructions typically have a fixed size.
◯ True ◯ False **Solution:** False. CISC typically uses variable length instructions.

(e) In a processor with a pipeline architecture, state registers are used to isolate the pipeline stages.
◯ True ◯ False **Solution:** True.

2 MIPS Single-Cycle Datapath (17 Points)

Consider the single-cycle implementation of a MIPS processor depicted in the image below. Suppose that the processor executes the instruction `ori $r20,$r23,0xc1`. The `$PC` register holds `0x1004'0004`. The state of the register file is given in the following table:

Register file	
Register	Content
`$r20`	`0x0000'0035`
`$r21`	`0x0000'1042`
`$r22`	`0x0000'1040`
`$r23`	`0x0000'1018`

Based on the given implementation and register contents, answer the questions below.
Note: For all the tasks the `0x` prefix is used to indicate hexadecimal values.

(a) (1 point) What value does the `$PC` register hold after executing the instruction?

Solution:
PC + 4 = 0x1004'0008

(b) (5 points) How is the instruction `ori $r20,$r23,0xc1` encoded in the instruction memory? State the binary representation of this instruction and describe your solution process. The opcode of `ori` is `0xd`. *Hint:* `ori` is an I-type instruction, the syntax of an `ori` instruction is `ori $rt,$rs,imm`. The performed operation is `R[rt] = R[rs] | imm`.

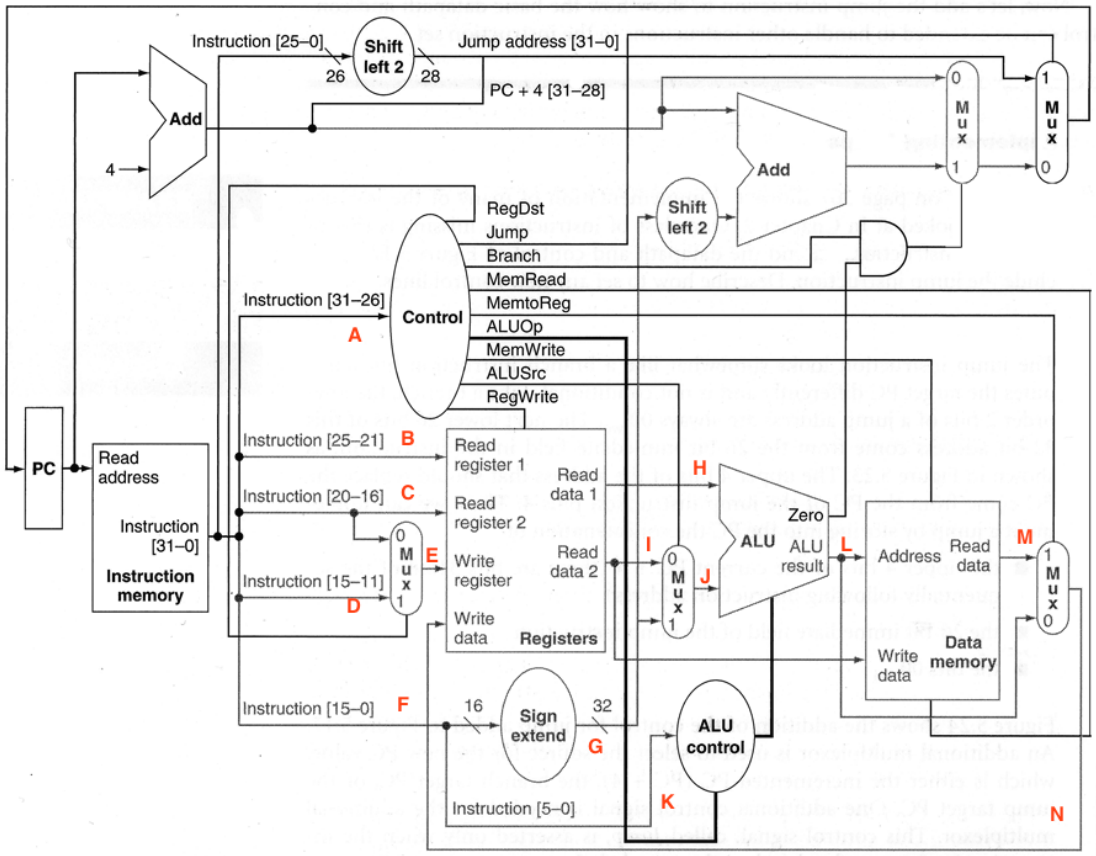
Solution:
(penalty if encoding not in binary)
I-Type format: opcode(6) | rs(5) | rt(5) | imm(16)
(1 point) opcode = 0xd = 0b00'1101
(1 point) rs = 23 = 0x17 = 0b0001'0111
(1 point) rt = 20 = 0x14 = 0b0001'0100
(1 point) imm = 193 = 0xc1 = 0b1100'0001
(1 point) encoding: 0xd | 0x14 | 0x17 | 0xc1 = 0b001101 | 10111 | 10100 | 0000 0000 1100 0001

(c) (4 points) What are the values of the control signals `RegDst`, `Jump`, `Branch`, `MemRead`, `MemtoReg`, `MemWrite`, `ALUsrc` and `RegWrite`? Also state "Do not Care" cases, if any, with "X".

RegDst	**Jump**	**Branch**	**MemRead**
MemtoReg	**MemWrite**	**ALUsrc**	**RegWrite**

Solution: (0.5 points each)
0 0 0 0
0 0 1 1

(d) (7 points) For each letter in the diagram, state the value of the signal on the corresponding wire. You may use binary, hexadecimal or decimal values. All (if any) undefined signals are to be marked with "X".



A	B	C	D
E	**F**	**G**	**H**
I	**J**	**K**	**L**
M	**N**		

Solution: (0.5 points each)

A 0xd (opcode)
B 0x14 (rs)
C 0x17 (rt)
D 0x0
E C (I-Type, mux=0)
F 0xc1
G 0xFFFFFFc1 (sign ext.)
H 0x0000'1018 ($r23)
I X
J G (I-Type, mux=1)
K 0x1
L H | J (bitwise or)
M X
N (mux=0)

3 C Programming (12 Points)

(a) (8 points) Write a C function that returns the largest prime number in an array. Choose an appropriate return value in case the array contains no prime numbers. The function declaration should look as follows:

```
int largestPrime(int array[], int size)
```

You can assume you are given the implementation of a function `int isPrime(int x) { ... }` that returns 1 (true) if `x` is prime and 0 (false) otherwise.

Solution:

```
int largestPrime(int array[], int size) {
	int largest = 0; // if no primes, return 0: 1 point
	int i; // 1 point
	for(i = 0; i < size; i++) { // 2 points for correct signature, 1 point for minor mistake
		if (isPrime(array[i]) && (array[i] > largest)) {
			// logical AND or two if clauses: 2 points
			// use of isPrime: 1 point
			largest = array[i];
		}
	}

	return largest; // 1 point
}


// additional points if maximum not already reached: 1 point
int main() {
	int x[6] = {1, 2, 3, 4, 5, 6};
	printf("%d", largestPrime(x, sizeof(x) / sizeof(x[0])));
}
```

(b) (2 points) Why do we need to pass the size of the array as an argument in the above function?

Solution: The array is referenced by a pointer to the first element. Therefore, the size is unknown.

(c) (2 points) How would you change the declaration of this function such that it operates on a pointer to integers?

Solution: `int largestPrime(int *array, int size)`

4 MIPS (10 Points)

The following MIPS assembly program is reading from Integer arrays `a` and `b` and writing to the Integer array `a`. Assume the base address of `a` and `b` is saved in register `$t0` and `$t1`, respectively, and that `sizeof(int) = 4`.

```
1  addi $t2, $zero, 4              // i = 4
2  addi $t3, $zero, 2
3  sw $t3, 0($t0)                  // a[0] =  ________________
4
5  loop:   lw $t3, 0($t0)          // read a[0]
6
7          beq $t2, 16, end
8
9          addi $t2, $t2, 4        // i++
10
11         add $t4, $t2, $t1       // $t4 = i + base address of b
12         lw $t5, 0($t4)          // $t5 = b[i]
13         add $t3, $t5, $t3       // $t3 = b[i] + a[0]
14
15         add $t5, $t2, $t0
16         sw $t3, 0($t5)          // a[i] = ________________
17
18         j loop
19
20 end:    sw $zero, 0($t0)        // a[0] = ________________
```

(a) (3 points) Fill the three blank lines 3, 16, and 20 in the comments above with suitable C pseudo code.

Solution:

```
1  (3) a[0] = 2;
2  (16) a[i] = b[i] + a[0];
3  (20) a[0] = 0;
```

(1 point each)

(b) (1 point) How many times does the loop iterate?

Solution: The register `$t2` (the counter variable) initially holds the value 4. It is incremented by 3 after the branch instruction until it reaches the value 16. Therefore, the loop is exectued four times.

(c) (6 points) Translate the above MIPS program to C code.

Solution:

```
1  int a[10];
2  int b[10] = { ... }
3
4  a[0] = 2;                              // 1 point
5  int j;                                 // optional 0.5 points if maximum not reached
6  for (j = 1; j <= 4; j++) {             // 2 points
7      a[j] = b[j] + a[0];                // 2 points
8  }
9  a[0] = 0;                              // 1 point
```