Instructions:

1. Answer all the questions in the space provided. Additional blank sheets will be provided, if required.
2. This is a **closed book/Notes** examination. No printed/written/projected material will be allowed *except for sheets provided by the instructor*
3. **Write your answers clearly and legibly**
4. The numbers within [ ] are marks and { } are time you want to spend on each of them

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1. [6] {6} We have seen the definition

$$cpu\ time = \frac{seconds}{program} = \frac{Instructions}{program} * \frac{cycles}{Instruction} * \frac{seconds}{cycle}$$

$$cpu\ time = \frac{seconds}{program} = \frac{Instruction\ Count * CPI}{Clock\ rate}$$

	CPI				
	T1	**T2**	**T3**	**T4**	**T5**
P1 (4GHz)	1	2	3	4	5
P2 (6 GHz)	2	2	2	2	6

Table 1

A program has 5 types of instructions T1 through T5. The number of cycles for each instruction type for two processors P1 and P2 is given in the above table. The clock rate of the two processors P1 and P2 are given as 4GHz and 6 GHz respectively.

a. [2] What is the average CPI for this program on P1 and P2? Assume instructions in the program are equally distributed among the different types.
b. [2] What is the peak performance of P1 (in instructions per second)?
   Peak performance is defined as the fastest rate at which a computer can execute any instruction sequence. In other words, a type of instruction that requires smallest CPI would determine the peak performance. For example, for P1 Type 1 (T1) instructions will determine the peak performance.
c. [2] What is the peak performance of P2 (in instruction per second)?

2. [12] {10} The table below summarizes execution time for two programs on three different computers. Using this table answer the following questions.
   a. [3] Calculate the total **execution time** for running both the programs on the three machines and identify the fastest machine in terms of total execution time

Table 2

b. [3] Measure the **relative performance** of the fastest machine with respect to other machines.

	Floating point ops.	Execution time in seconds		
		Computer A	Computer B	Computer C
Program 1	10,000,000	1	10	20
Program 2	100,000,000	1000	100	20

c. [6] Suppose the total number of FLOPS executed in the workload is equal in both the programs. That is, program 1 runs 10 times as often as program 2.

i. [3] Find which machine is fastest for this new workload
ii. [3] by how much?

3. [4] {3}
a. [2] Define **Instruction Set Architecture**
b. [2] Name at least 2 levels of **abstractions** we have seen in class

4. [6] We have extensively discussed MIPS in class.
a. [1] Name two other assembly language you are familiar with

b. Consider a digital computer that has a memory unit with 24 bits per word. The instruction set consists of 150 different operations. All instructions have an operation code field (opcode) and an address field (allowing for only one address). Each instruction is stored in one word of memory.

i. [2] How many bits are needed for the opcode?
ii. [1] How many bits are left for the address part of the instruction?
iii. [1] What is the maximum allowable size for memory?
iv. [1] What is the largest unsigned binary number that can be accommodated in one word of memory?

5. [5]
a. [1] State what the following MIPS instruction does?
sll $t2, $s0, 8
b. [2] Identify the **format** this machine code represents
c. [2] What is the meaning of this instruction in terms of its end result?

6. [8] Fill the Table 3 with appropriate control signal values against each instruction. The instructions are:
a. add $a0 $a1, $a2
b. jump 25
c. and $a0 $a1, $a2
d. slt $s1, $s2, $s3

	Control Signals							ALUOp	
Instruction	RegDst	ALUSrc	Mem2Reg	RegWrite	MemRead	MemWrite	Branch	Op 1	Op 0
add									
Jump									
and									
slt									

Table 3: Control values for a single cycle implementation of MIPS instruction

7. [15] We would like to add the instruction **addi** (add immediate) to the single-cycle datapath described in class. Use the figure 1 provided (in the last sheet) as a reference to answer the following questions:

a. [1] What is the format of this instruction?
b. [2] What additions will you make to the datapath?
c. [1] Does the Instruction fetch change? If so, state how?
d. [1] Does the Register fetch change? If so, state how?
e. [3] Fill the right hand side of with appropriate entries: ALU= (?) + (?)
f. [3] Where in the register field (the **bit range**) is the result of ALU written?
g. [3] What are the control signal values for this instruction? Recreate Table 3 and fill-in the values for this instruction.

8. [8]

Various blocks in the datapath take various amount of time to do their work. The time required in various blocks are given as follows: Instruction Mem: 200ps; Adder: 70ps; Mux: 20ps; ALU:90ps; Regs:90ps; Data Mem:250ps;

a. [3] Compute the total time needed to complete **and** instruction.
b. [2] Write the MIPS instructions corresponding to the machine code $(00000000)_{16}$.
c. [3] What is a NOOP instruction?

Figure 1: Single Cycle Datapath with controls