The University of Alabama in Huntsville
Electrical & Computer Engineering Department
CPE 431 01
Test 1 Solution

1. (1 point) An ____embedded computer____ is a computer inside another device used for running one predetermined application or collection of software.

2. (1 point) A _DVD__ is an optical storage medium with a storage capacity of more than 4.7 GB. It was initially marketed for entertainment and later for computer users.

3. (1 point) A program that manages the resources of a computer for the benefit of the programs that run on that machine is a(n) _operating system_.

4. (1 point) _Chip_ is a nickname for a die or integrated circuit.

5. (1 point) To specify a register choice from a 512 register register file requires __9_ bits.

6. (20 points) Using the following MIPS program, determine the instruction format for each instruction and the decimal values of each instruction field. Do not worry about whether this program does anything useful.

```
        addi   $v0, $zero, 0
loop:   lw     $v1, 0($a0)
        sw     $v1, 0($a1)
        addi   $a0, $a0, 4
        beq    $v1, $zero, loop
```

Instruction	Type	op	rs	rt	Immediate
addi	I format	8	0	2	0
lw	I format	35	4	3	0
sw	I format	43	5	3	0
addi	I format	8	4	4	4
beq	I format	4	3	0	-4

8. (20 points) Given the bit pattern:

$1010\ 1101\ 0001\ 0000\ 0000\ 0000\ 0000\ 0010_2$

what does it represent, assuming that it is

a. a two's complement integer?
b. an unsigned integer?
c. a single precision floating-point number?
d. a MIPS instruction?

a. $-2^{31}+2^{29}+2^{27}+2^{26}+2^{24}+2^{20}+2^{2}$ = -2147483548 + 536870912 + 134217728 + 67108864 + 16777216 + 1048576 + 2 = -1391460250

b. $2^{31}+2^{29}+2^{27}+2^{26}+2^{24}+2^{20}+2^{2}$ = 2147483548 + 536870912 + 134217728 + 67108864 + 16777216 + 1048576 + 2 = 2903506846

c. Sign = 1
Exponent = $01011010_2 = 90_{10}$
Fraction = 001 0000 0000 0000 0000 $0010_2 = 2^{-3} + 2^{-22} = (0.125 + 2.384 \text{ x}10^{-7})_{10} = 0.1250002384_{10}$
Number = $(-1)^S$ x $(1+\text{Fraction})\text{x}2^{(\text{Exponent} - \text{Bias})} = (-1)1\text{x}(1 + 0.1250002384)\text{x}2^{(90\text{-}127)} = -8.185 \text{ x}10^{-12}$

d. Opcode = 1010 112 = 4310, instruction is sw and I-format, other fields are
rs = $01000_2 = 8_{10}$ or \$t0, rt = $10000_2 = 16_{10}$ or \$s0, immediate = 0000 0000 0000 $0010_2 = 2_{10}$
sw \$s0, 2(\$t0)

9. (10 points) Show the IEEE 754 binary representation for the floating-point number 20.5_{ten} in single and double precision.
$20.5_{10} = 10100.1_2$, After normalizing, we get $1.01001_2 \text{ x } 2^4$
Sign = 0 in both single and double
Bias = 127 for single precision and 1023 for double precision
Single precision: Exponent –127 = 4, Exponent = 131
Double precision: Exponent – 1023 = 4, Exponent = 1027

Single Precision: 0100 0001 1010 0100 0000 0000 0000 0000
Double Precision: 0100 0000 0011 0100 1000 0000 0000 0000
0000 0000 0000 0000 0000 0000 0000 0000

10. (10 points) Pseudoinstructions are not part of the MIPS instruction set but often appear in MIPS programs. For each pseudoinstruction in the following table, produce a minimal sequence of actual MIPS instructions to accomplish the same thing. You may need to use \$at for some of the sequences. In the table, big refers to a specific number that requires 32 bits to represent and small to a number that can fit in 16 bits.

Pseudoinstruction	What it accomplishes	MIPS Instruction(s)
`li $t1, small`	`$t1 = small`	`addi $t1, $zero, small`
`move $t1, $t2`	`$t1 = $t2`	`add $t1, $zero, $t2`

`beq $t2, big, L`	`if ($t2 = big) go to L`	`lui $at, big[31..16]`
		`ori $at, $at, big[15..0]`
		`beq $at, $t2, L`

11. (10 points) Consider two different implementations, P1 and P2 of the same instruction set. There are five classes of instructions (A, B, C, D, E) in the instruction set. P1 has a clock rate of 4 GHz. P2 has a clock rate of 6 GHz. The average number of cycles for each instruction class for P1 and P2 is as follows:

Class	CPI on P1	CPI on P2
A	1	2
B	2	2
C	3	2
D	4	4
E	3	4

Assume that peak performance is defines as the fastest rate that a computer can execute any instruction sequence. What are the peak performances of P1 and P2 expressed in instructions per second?

Peak performance is obtained in P1 by a sequence of instructions which all come from class A. Peak performance is obtained in P2 by a sequence of instructions which come from classes A, B, or C.

For P1: $$\frac{instructions}{second} = \frac{\frac{cycles}{second}}{\frac{cycles}{instruction}} = \frac{4 \times 10^9}{1} = 4 \times 10^9$$

For P2: $$\frac{instructions}{second} = \frac{\frac{cycles}{second}}{\frac{cycles}{instruction}} = \frac{6 \times 10^9}{2} = 3 \times 10^9$$

12. (10 points) Consider program P, which runs on a 1 GHz machine M in 10 seconds. An optimization is made to P, replacing all instances of multiplying a value by 16 (mult X, X, 16) with four instructions that set x to x + x four times (add X, X; add X, X; add X, X; add X, X). Call this new optimized program P'. The CPI of a multiply instruction is 10, and the CPI of an add is 1. After recompiling, the program now runs in 9 seconds on machine M. How many multiplies were replaced by the new compiler? Let x be the number of multiplies

ET = ($CC_{affected}$ + $CC_{unaffected}$) * CT

ET_P = (CC_{mult} + $CC_{unaffected}$) * 1 ns

(a) 10 s = (x * CPI_{mult} + $Cc_{unaffected}$) * 1 ns
= (10x + $Cc_{unaffected}$) * 1 ns

$ET_{P'}$ = ($CC_{four\ adds}$ + $CC_{unaffected}$) * 1 ns

(b) 9 s = (x * 4*CPI_{add} + $CC_{unaffected}$) * 1 ns
= (4x + $CC_{unaffected}$) * 1 ns

Multiply (b) by –1 and add to (a), yielding 6x = 1*10^9, x= 1.67*10^8

13. (15 points) One user has told you that three programs constitute the bulk of his workload, but he does not run them equally. The user wants to determine how these three computers compare when the workload consists of different mixes of these three programs.

Suppose the total execution time is equally divided among the three programs on computer C. Find which computer is fastest for this workload and by what factor.

Program	FLOPS	Computer A	Computer B	Computer C	Weight
1	5 x 10^9	2 s	5 s	10 s	6
2	20 x 10^9	20 s	20 s	20 s	3
3	40 x 10^9	200 s	50 s	15 s	4

$$WAM_A = \sum_{i=1}^{n} w_{Ai} ET_{Ai} = (6/13)*2 + (3/13)*20 + (4/13)*200 = (12+60+800)/13 = 872/13$$

$$WAM_B = \sum_{i=1}^{n} w_{Bi} ET_{Bi} = (6/13)*5 + (3/13)*20 + (4/13)*50 = (30+60+200)/13 = 290/13$$

$$WAM_C = \sum_{i=1}^{n} w_{Ci} ET_{Ci} = (6/13)*10 + (3/13)*20 + (4/13)*15 = (60+60+60)/13 = 180/13$$

$$\frac{P_C}{P_A} = \frac{ET_A}{ET_C} = \frac{WAM_A}{WAM_C} = \frac{872/13}{180/13} = 4.84 \qquad \frac{P_C}{P_B} = \frac{ET_B}{ET_C} = \frac{WAM_B}{WAM_C} = \frac{290/13}{180/13} = 1.61$$

So, C is 4.84 times as fast as A and 1.61 times as fast as B.