The University of Alabama in Huntsville
ECE Department
CPE 431 01
Test 2
November 10, 2016

Name: _____

1. (1 point) A _____ means that the hardware cannot support the combination of instructions that we want to execute in the same clock cycle.

2. (10 points) The importance of having a good branch predictor depends on how often conditional branches are executed. Together with branch predictor accuracy, this will determine how much time is spent stalling due to mispredicted branches. In this exercise, assume that the breakdown of dynamic instructions into various instruction categories is as follows:

R-type	BEQ	JMP	LW	SW
40%	25%	5%	25%	5%

Also, assume the following branch predictor accuracies:

Always-Taken	Always-Not-Taken	2-Bit
45%	55%	85%

Stall cycles due to mispredicted branches increase the CPI. What is the extra CPI due to mispredicted branches with the (a) always-taken predictor, (b) always-not-taken predictor and (c) the 2-bit predictor? Assume that branch outcomes are determined in the MEM stage, that there are no data hazards, and that no delay slots are used.

3. (20 points) Here is a series of address references given as byte addresses: 118, 483, 2069, 321, 368, 1077, 1505, 812, 2832, 373, 1411, 511, 1463, 690, 4820, 1714, 1508, 1080. Assuming a two-way set associative-mapped cache with two-word blocks and a total size of 16 words (32 bits) that is initially empty and uses LRU, (a) label each reference in the list as a hit or a miss and (b) show the entire history of the cache, including tag and data.

Byte Address (Decimal)	Byte Addres (Hexadecimal)	
118	76	
483	1E3	
2069	815	
321	141	
368	170	
1505	5E1	
812	32C	
2832	B10	
373	175	
1411	583	
511	1FF	
122	7A	
690	2B2	
4820	12D4	
1714	6B2	
1508	5E4	
2070	816	
1080	438	

4. (1 point) A _____ occurs when an accessed page is not present in main memory.

5. (15 points) a) Schedule the following code on a 2-issue pipeline in which one slot takes lw/sw instructions and the other slot takes R-type and branch instructions. You have forwarding from the EX stage only and the branch completes in the ID stage.

```
Loop: lw    $s2, 0($s0)
      sub   $s4, $s2, $s3
      sw    $s4, 0($s0)
      lw    $s2, 4($s0)
      sub   $s4, $s2, $s3
      sw    $s4, 4($s0)
      lw    $s2, 8($s0)
      sub   $s4, $s2, $s3
      sw    $s4, 8($s0)
      addi  $s0, $s0, 12
      bne   $s0, $t3, Loop
```

Cycle	Issue Slot R type/Branch	Issue Slot lw/sw
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		

6. (1 point) The _____ contains the address information required to identify whether a word in the cache corresponds to the requested word.

7. (15 points) In this exercise we look at memory locality properties of matrix computation. The following code is written in C, where elements within the same row are stored contiguously. Assume each word is a 32-bit integer.

```
for (I = 0; I < 8; I++)
  for (J = 0; J < 8000; J++)
    for (K = 0; K < 2000; K++)
      A[I][J][K] = B[J][0][I] + A[I][J][K];
```

(a) References to which variables exhibit temporal locality?
(b) References to which variables exhibit spatial locality?

8. (1 point) _____ states that if an item is referenced, items whose addresses are close by will tend to be referenced soon.

9. (1 point) In the case where memory and cache have different values for the same memory location, the cache and memory are said to be _____ .

10. (15 points) Virtual memory uses a page table to track the mapping of virtual addresses to physical addresses. The following table is a stream of virtual addresses as seen on a system. Assume 4 KiB pages, byte addressing, a four-entry fully associative TLB, and true LRU replacement. If pages must be brought in from disk, increment the next largest page number. Given the address stream, and the shown initial state of the TLB and page table, show the final state of the system. Also list for each reference if it is a hit in the page table, or a page fault.

12948, 49419, 46814. 13975, 40004, 12707, 52236

TLB

Valid	Tag	Physical Page Number
1	11	12
1	7	4
1	3	6
0	4	9

Page table

VPN	Valid	Physical page or in disk
0	1	5
1	0	Disk
2	0	Disk
3	1	6
4	1	9
5	1	11
6	0	Disk
7	1	4
8	0	Disk
9	0	Disk
10	1	3
11	1	12
12	0	Disk

11. (20 points) Using the code below, unroll the loop so that two iterations are executed. Arrange the unrolled code to maximize performance. You may assume that the loop executes a multiple of two times. Calculate the number of cycles for the original and for the unrolled, rearranged code. Assume full forwarding and one cycle delay for taken branches.

```
       addi  $t2, $zero, $zero
Loop:  sll   $t3, $t2, 2
       add   $t0, $t3, $s6
       lw    $t0, 0($t0)
       lw    $t0, 0($t0)
       mul   $t1, $t0, $s2
       add   $t0, $t3, $s7
       lw    $t0, 0($t0)
       lw    $t0, 0($t0)
       mul   $t0, $t0, $s3
       add   $t1, $t0, $t1
       add   $t0, $t3, $s8
       sw    $t1, 0($t0)
       addi  $t2, t2, 1
       slt   $t4, $t2, 48
       bne   $t4, $zero, Loop
```