



1. (10 points) In the pipeline architecture, the control hazards can be solved by pipeline stall which is stalled one extra clock cycle before starting. If a program has 15% conditional branches instructions. Please estimate the impact on the clock cycles per instruction (CPI) of stalling on branches. Assume all other instructions have a CPI of 1.
2. (10 points) Identify all of the data dependencies in the following code. Which dependencies are data hazards that can be resolved via forwarding? Which dependencies are data hazards that will cause a stall?

```
add $3, $4, $2
add $5, $3, $1
lw  $6, 100($3)
add $7, $3, $6
```

3. (15 points) A computer system has 32 address lines and 32-Kbyte cache. Each cache block size is 32-byte. For the following cases, how many tag-bit is required for each cache block? (15%)
 - (a) A direct mapped cache
 - (b) A fully associative cache
 - (c) A 8-way set associative cache
4. (10 points) Suppose we have made the measurements of average CPI for instructions and average the instruction frequencies for gcc and spice, as shown in Table 1. Please compute the effective CPI.

Table 1

| Instruction | Average CPI | gcc | spice |
|--------------------|------------------|-----|-------|
| Arithmetic | 1.0 clock cycles | 48% | 50% |
| Data Transfer | 1.4 clock cycles | 33% | 41% |
| Conditional branch | 1.7 clock cycles | 17% | 8% |
| Jump | 1.2 clock cycles | 2% | 1% |

5. (5 points) The performance of a 200 MHz microprocessor P is measured by execution 10,000,000 instructions of benchmark code, which is found to take 0.125 s. What is the value of CPI?
6. Consider two RAID disk systems that are meant to store 10 terabytes of data (not counting any redundancy). System A uses RAID 1 technology and System B uses RAID 5 technology with four disks in a "protection group".
 - (3 points) (a) How many more terabytes of storage are needed in System A than in System B?
 - (3 points) (b) Suppose an application writes one block of data to the disk. If reading or writing a block takes 30 ms, how much times will the write take on System A in the worst case? How about on System B in the worst case?
 - (4 points) (c) Is System A more reliable than System B? Why or Why not?



7. (5 points) (a) Find the average memory access time (AMAT) for a processor with a 2 ns clock, a miss penalty of 20 clock cycles, a miss rate of 0.05 misses per instruction, and a cache access time (including hit detection) of 1 clock cycle. Assume that the read and write miss penalties are the same and ignore other write stalls.
- (5 points) (b) (Continued Problem 2(a)) Suppose we can improve the miss rate to 0.03 misses per reference by doubling the cache size. This causes the cache access time to increase to 1.2 clock cycles. Using the AMAT as a metric, determine if this is a good trade-off.
8. (10 points) You are going to enhance a computer, and there are two possible improvements: either makes multiply instructions run four times faster than before, or make memory access instructions run two times faster than before. You repeatedly run a program that takes 100 seconds to execute. Of this time, 20% is used for multiplication, 50% for memory access instructions, and 30% for other tasks. What will the speedup be if you improve only multiplication? What will the speedup be if you improve only memory access? What will the speedup be if both improvements are made?
9. (5 points) (a) What is the hexadecimal representation for the IEEE 754 binary representation for the number $-20\frac{19}{32}$ in single precision?
- (7 points)(b) Perform $x + y$ with $x = 0100\ 0110\ 1101\ 1000\ 0000\ 0000\ 0000\ 0000$ and $y = 1011\ 1110\ 1110\ 0000\ 0000\ 0000\ 0000\ 0000$ representing single precision IEEE 754 floating-point numbers. What is the result in decimal?
10. (8 points) Translate each of the following problems from base ten notation into 2's complement notation (using patterns of 6 bits), and convert any subtraction problem to an equivalent addition problem, then perform the addition. Show your derivation in detail. (A)23+13 (B)-12-13