(1) (5) List the 4 classes of benchmarks, give an example for each class, and tell me what the perfect benchmark would be.

(2) (5) What is the definition of a basic block? Why is there a desire to create larger ones?

(3) (5)What is a predicated instruction? What are the advantages to using predicated instructions? When would you *not* want to use one?

(4) (7) Convince me you understand Tomasulo’s algorithm. (In other words, explain what it is, how it works, why it works, etc.)

(5) (7) Describe VLIW, and list the advantages and disadvantages of this approach.

(6) (5) There are 3 kinds of Hazards - Structural, and two others. List the other two, and give brief descriptions of all three.

(7) (5) Why is branch prediction important? What performance enhancing techniques have made it so? Give 1 static and 2 dynamic branch prediction approaches (in order of increasing effectiveness).

(8) (10) Assume an enhancement is made to a computer that improves some mode of execution by a factor of 10. Enhanced mode is used 50% of the time, measured as a percentage of the execution time when the enhanced mode is in use. (Remember that Amdahl's Law depends on the fraction of the original, *unenhanced* execution time that can make use of the enhanced mode.)

a) What is the speedup that has been obtained from the fast mode?

b) What percentage of the original execution time has been converted to fast mode?

(9) (10) A single statistic, such as a mean, may not be a useful representation of the performance if there is a lot of variance in the execution times of the benchmarks used. As an example, the CPU pipeline and hard disk subsystem of a computer execute their respective basic processing steps at speeds that differ (typically) by a factor of 10 million. This is a difference in speed greater than the difference between a jetliner in flight and a snail gliding along a leaf.

a) What are the arithmetic means of two sets of benchmark measurements, one with nine values of 10ˆ7 and a single value of 1, and the other set with 9 values of 1 and a single value of 10ˆ7?

b) How do these medians compare with the data set medians?

c) Which outlying data point affects the arithmetic mean more, a large or a small value?

d) Repeat a) and b) for two sets of 10 benchmarks measurements where the outlying value is only a factor of two away from the rest of the values.

e) How representative of the entire set does the arithmetic mean seem for this more narrow range of performance values?

(10) (8) Tomasulo's algorithm has one disadvantage: Only one result can complete and use the Common Data Bus (CDB) per clock (per CDB). Give a sample code sequence that will stall due to CDB contention (be sure to indicate the instruction latencies you are assuming!), and extend this to explain in words the characteristics of any code sequence that will eventually experience structural hazard stall given *n* CDB's.

(11) (8) Many high performance machines employ speculation.

a) When an instruction is correctly speculated, what is the effect on the three factors (dynamic instruction count, average clocks per instruction, clock cycle time) that comprise the CPU time formula?

b) When speculation is incorrect, it is possible for CPU time to increase. Which factor(s) of the CPU time formula best model this increase, and why?

(12) (25) Consider the following MIPS assembly code.

```
LD      R1, 45(R2)
DADD    R7, R1, R5
DSUB    R8, R1, R6
OR      R9, R5, R1
BNEZ    R7, target
DADD    R10, R8, R5
XOR     R2, R3, R4
```

a) Identify each dependence by type; list the two instructions involved; identify which instruction is dependent; and, if there is one, name the storage location involved.

Assume the 5-stage MIPS pipeline (IF, ID, EX, MEM, WB), and a register file that writes in the first half of a clock cycle and reads in the second half. Which of the dependencies that you listed in part (a) become hazards, and which do not? Why?