CS 2200 - Introduction to Systems
Fall 2016
Homework 5

Rules:

- Please print a copy of the assignment and handwrite your answers. No electronic submissions are allowed. **Please print as one double-sided page.**
- This is an individual assignment. No collaboration is permitted.
- Due Date: 12th October 2016 – 6:05 PM . Bring your BuzzCard.

Name (please print):CS 2200 **GTLogin:**cs2200 **Section**A2200

1. **[30 points]** You are deciding whether to upgrade your architecture from LC4 to LC5. You only intend to run one program on these architectures, and it uses three instructions: Instruction 1, Instruction 2, and Instruction 3. The number of cycles for each instruction and its frequency in the program is given below. **Compute the speedup in execution time for this program. Based on this, should you upgrade?**

	Instruction 1	Instruction 2	Instruction 3
Cycles for LC4	3	5	7
Cycles for LC5	2	7	6
Frequency in Program	30%	45%	25%

P is the program. i is the instruction (1, 2, or 3).

Execution Time of P = sum(# cycles for i * seconds per cycle * how many times i is run)

cycles for i is given to us in the table

Seconds per cycle is some constant 'S'

How many times i is run = num_instructions_total * frequency of i

num_instructions_total is some constant 'T'

Frequency of i is given to us in the table

A: Execution Time of P = (3)(S)(.3T) + (5)(S)(.45T) + (7)(S)(.25T) = ST(4.9)

B: Execution Time of P = (2)(S)(.3T) + (7)(S)(.45T) + (6)(S)(.25T) = ST(5.25)

Speedup = Execution time on B / Execution time on A = 5.25ST / 4.9 ST = 1.07.

DON'T UPGRADE! A number > 1 indicates time after is larger, meaning slower.

Also accept speedup value of 4.9ST / 5.25ST = 0.93 as long as justification corresponds

2. **[40 points]** You've been tasked with buying a CPU for your new server. You've narrowed your search down to the 1.80 GHz Intel Xeon E5-4610 and the 2.10 GHz Intel Xeon E5-4620. SPEC has run various benchmark programs on both of these processors and recorded their results here:
   4610: https://www.spec.org/cpu2006/results/res2016q4/cpu2006-20160919-44247.pdf
   4620: https://www.spec.org/cpu2006/results/res2016q4/cpu2006-20160919-44249.pdf

   Assume we only care about benchmarks 401.bzip2, 403.gcc, and 473.astar. Also assume that the running time of the benchmark is the median peak value in seconds.

   a) Give the harmonic mean and arithmetic mean of the running times for the three programs for both CPUs to the nearest tenth. Based on this, which CPU should you buy?

   4610: Arithmetic Mean = (698 + 360 + 352) / 3 = 470s

   4620: Arithmetic Mean = (497 + 269 + 250) / 3 = 338.666… = 338.7s

   4610: Harmonic Mean = 1/ ((1/698 + 1/360 + 1/352) / 3) = 425.45… = 425.5s

   4620: Harmonic Mean = 1/ ((1/497 + 1/269 + 1/250) / 3) = 308.339… = 308.3s

   Both means for the given benchmarks are lower on the 4620 processor, so we should buy the 4620.

   b) (**True** or **False**): Harmonic mean is always smaller than arithmetic mean. If false, give a counterexample.

   False - if all values are the same, then harmonic and arithmetic mean are equal.

3. **[30 points]** Consider the Conte-200, a 4-stage pipeline processor. Suppose that for the Conte-200, its fetch stage needs at least 0.4 ns, its decode stage needs at least 0.6ns, its execute stage (ALU and Memory operations happen to be combined into one stage for the Conte-200) needs at least 1.1 ns, and its writeback stage needs at least 0.01ns. For the following questions, assume that 9001 instructions are executed and the compiler was smart enough to magically eliminate any and all dependencies

   a) What is the maximum operating frequency of the Conte-200? Why? Use proper units.

   Bottleneck stage is EX - takes 1.1ns.

   The clock cycle has to be long enough to accommodate this and so will be 1.1ns.

   1.1ns/1 cycle => 909090909.091 cycles/second => 0.9GHz

   b) Suppose that with data forwarding, the Conte-200's maximum operating frequency becomes 0.8 GHz. What would the speedup be if we implemented data forwarding? Given the speedup, should we implement data forwarding? Provide reasoning.

   Time per cycle with forwarding: 1/0.8 GHz = 1.25ns

   Time per cycle without forwarding: 1/0.9GHz = 1.1ns

   Since the compiler got rid of all dependencies, we have a CPI of 1.

   Speedup = (1.1 * 1 * 9001)/(1.25 * 1 * 9001) = 0.88

   Do not implement dataforwarding because the speedup less than 1 indicates we would actually slow down.