You may work in pairs for this assignment. If you choose to work with a partner, make sure only one of you submits a solution, and you paste a copy of the Partners Template that contains the names and PIDs of both students at the beginning of the file.

Prepare your answers to the following questions in a plain text file. Submit your file to the Curator system by the posted deadline for this assignment. No late submissions will be accepted. To receive credit, you must show your computations, and explicitly apply Amdahl's Law where specified.

You will submit your answers to the Curator System (www.cs.vt.edu/curator) under the heading `MIPS02`.

1. For a certain processor, with a 2GHz clock rate, assume the following average CPI for each category of instruction:

Category	average CPI
arithmetic	1
load/store	12
branch	5

Executed on a single processor, a certain program requires performing 2.56E9 arithmetic instructions, 1.28E9 load/store instructions, and 2.56E8 branch instructions.

The program described above is modified for parallel execution on multiple cores; each core has the same clock rate as the original processor. The changes to the program alter the number of instructions that must be performed, per core, as follows. For arithmetic and load/store instructions, the number of instructions executed per core will be divided by 0.8 * p, where p is the number of cores used. However, the number of branch instructions per core will be the same as the number in the original program.

a) **[14 points]** Fill in the following table (round each answer to the nearest hundredth):

# cores	per core # arith instr	per core # load/store instr	per core # branch instr	per core # cycles	exec time in seconds	speedup relative to 1 core
1	2.56E9	1.28E9	2.56E8			1.00
4						
8						

Copy the template from the Assignments page, and paste it into your text file, to record your answers.

b) **[10 points]** What must the CPI for load/store instructions be reduced to in order for the performance, running the program on a single core, to equal the performance of the program running on 4 of the original cores? Justify your conclusion precisely.

2. A company currently produces three different processors, all executing the same set of instructions:

- P1 has a 2.8 GHz clock rate and an advertised average CPI of 1.2
- P2 has a 3.2 GHz clock rate and an advertised average CPI of 1.6
- P3 has a 3.8 GHz clock rate and an advertised average CPI of 1.8

a) **[12 points]** Using IPS (instructions per second) as your only criterion, and accepting the information given above, which processor offers the best performance? Justify your conclusion precisely.

b) **[12 points]** It takes 42 seconds (of CPU time) to execute a certain benchmark on P1. How many machine instructions are executed when that benchmark is run on P1? Justify your conclusion precisely.

c) **[12 points]** The company would like to reduce the execution time of that benchmark on P1 by 25%, but the redesign (of P1) they've come up with would entail increasing the average CPI by 10%. What clock rate must they apply in order to achieve their goal? Justify your conclusion precisely.

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3. Consider a computer running a program that requires 300 seconds, with 60 seconds spent executing floating point instructions, 120 seconds executed load/store instructions, 90 seconds spent executing branch instructions, and the rest spent executing other instructions.

a) **[10 points]** Suppose the execution time of floating point instructions is reduced by 40%. Use Amdahl's Law to determine what speedup would be achieved for that program. Round your answer to the nearest one-thousandth.

b) **[10 points]** Can the total time can be reduced by 25% by reducing only the time for branch instructions? If so, explain how. If not, explain why. Use Amdahl's Law to justify your answer.

c) **[10 points]** Suppose we have technologies to improve the performance of these three types of instructions (floating point instructions, memory instructions, and branch instructions) by a factor of 2. Suppose, however, we have to choose only one type to improve for some reasons (e.g., labor, space/power constraints, etc.). Which one should we choose?

d) **[10 points]** Suppose that you have performed the optimization chosen in part **c)**. Now, suppose you can do the same thing once more (i.e., you pick any of the three types and improve its performance by a factor of 2), would you choose the same type of instruction to optimize? Use Amdahl's Law to justify your answer.