Question 3 (20 points): You have been hired as a performance expert to help XYZ Corporation assess some potential improvements to their best-selling machine. The most popular program run on this machine is dominated by the class of instructions C. Instructions in class C make up 60% of the total instructions, and on average, instructions from class C take 3 cycles to execute. For the remaining 40% of instructions, the average time is 1 cycle per instruction. The execution time of this original machine is T_{orig}.

The first proposed design change will reduce the average number of cycles for class C to 2 cycles per instruction, but will also increase the clock cycle time by 20%. The execution time for this first option is T_{Opt1}.

The second proposed design change will decrease the clock cycle time by 25%, but will increase the average cycles per instruction for class C to 4. The average CPI for the other classes will be unchanged. The execution time for this second option is T_{Opt2}.

Note: You do not need the instruction count or the clock cycle of the original machine to solve the problem, but if you want to have these numbers you can assume that the popular program has 10000 instructions and that the original machine was $2.0GHz$.

Given budget constraints, XYZ Corp can only afford to approve one of these changes.

a. **(8 points)** Is the machine proposed in the first option faster or slower than the original machine? By how much?

b. **(8 points)** Is the machine proposed in the second option faster or slower than the original machine? By how much?

c. **(4 points)** How much faster is the better design compared with the other proposal?

Original Machine: I = # of instructions, S = clock time

$$T_{orig} = (0.6I \times 3 + 0.4I \times 1) \times C = 2.2I \times C$$

Option 1:

$$T_{Opt1} = (0.6I \times 2 + 0.4I \times 1) \times 1.2 \times C = 1.92I \times C$$

Option 2:

$$T_{Opt2} = (0.6I \times 4 + 0.4I \times 1) \times 0.75 \times C = 2.1I \times C$$

a) Option 1 is faster by $\frac{2.2IC}{1.92IC} = 1.15$ times.

b) Option 2 is faster by $\frac{2.2IC}{2.1IC} = 1.05$ times.

c) Option 1 is $\frac{2.1}{1.92} = 1.09$ times faster than Option 2.