Name: **SOLUTION**
Student #: ________________

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COE 308 – Computer Architecture (T031)

Quiz # 01

***** Show all your work. No credit will be given if work is not shown! *****

Suppose that a program is being run on a processor consists of the following instruction mix:

Operation	Frequency	Clock cycle count per instruction
ALU operations	35%	4
Loads	20%	2
Stores	25%	2
Branches	20%	3

With the current processor, only **20%** of all ALU operations write results directly to memory, the remaining ALU operations write the results into registers. A designer decides to investigate a modified architecture for the processor by adding new ALU operations such that **all results** from ALU operations are written into registers, and, hence, require additional Store commands. The new ALU operations have a clock cycle of 2. By what **percentage** the modified processor's clock cycle should be faster/slower than the current processor's clock cycle so that both processors have the same execution time?

Solution:

Execution time = CPU time

CPI_{old} = 35% * 4 + 20% * 2 + 25% * 2 + 20% * 3 = 2.9

CPU time_{old} = CPI_{old} * $\text{Instruction Count}_{old}$ * Clock Cycle_{old}
= 2.9 * $\text{Instruction Count}_{old}$ * Clock Cycle_{old}

With modified architecture:

ALU operations: (35% * 20%) operations use the new ALU operations with 2 clock cycles per instruction, and
35% - (35% * 20%) operations use the original ALU operations with 4 clock cycles per instruction

Load operations: No change

Store operations: (25% + (35% * 20%)) operations with 2 clock cycles

Branches: No change

Overall program becomes 100% + (35% * 20%) = 107%

CPI_{new} = [(35% * 20%) * 2 + (35% - (35% * 20%)) * 4 + 20% * 2 + (25% + (35% * 20%)) * 2 + 20% * 3] / 107%
= 2.9 / 1.07 = 2.71

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$\text{CPU time}_{\textbf{new}} = \text{CPI}_{\textbf{new}} * \text{Instruction Count}_{\textbf{new}} * \text{Clock Cycle}_{\textbf{new}}$
$= 2.71 * (107\% * \text{Instruction Count}_{\textbf{old}}) * \text{Clock Cycle}_{\textbf{new}}$
$= 2.9 * \text{Instruction Count}_{\textbf{old}} * \text{Clock Cycle}_{\textbf{new}}$

Since we require that ($\text{CPU time}_{\textbf{new}}$) is equal to ($\text{CPU time}_{\textbf{old}}$), then

$\text{CPU time}_{\textbf{new}} = \text{CPU time}_{\textbf{old}}$
$2.9 * \text{Instruction Count}_{\textbf{old}} * \text{Clock Cycle}_{\textbf{new}} = 2.9 * \text{Instruction Count}_{\textbf{old}} * \text{Clock Cycle}_{\textbf{old}}$
$\text{Clock Cycle}_{\textbf{new}} = \text{Clock Cycle}_{\textbf{old}}$

Thus, $\text{Clock Cycle}_{\textbf{new}}$ must be equal to $\text{Clock Cycle}_{\textbf{old}}$ for the ($\text{CPU time}_{\textbf{new}}$) to be equal to ($\text{CPU time}_{\textbf{old}}$).

Hence, the modified processor's clock cycle must be **0%** faster than the original processor's clock cycle for the execution time to be the same.