CMSC611: Advanced Computer Architecture
Extra Credit Homework 1 Solution

1. In order to compute the weighted average CPI, we need to find the clock cycles for each instruction type and the total instruction count. Then, we calculate the weighted average as

$$\mathrm{CPI}_{\mathrm{average}} = \frac{\mathrm{ClockCycles}_{\mathrm{total}}}{\mathrm{InstructionCount}_{\mathrm{total}}} = \frac{\sum_{k=1}^{K} \mathrm{ClockCycles}_k \times \mathrm{InstructionCount}_k}{\mathrm{InstructionCount}_{\mathrm{total}}}$$

where K is the number of instruction types. Based on the initial values of ARRAY[100] and ARRAY[200], the loop "AGAIN" only iterates once. So, we only need to count each instruction once for calculating the clock cycle, and the number of total instruction count is 12. Details of each instruction and its corresponding clock cycle are listed on the following table:

Instruction	Clock Cycles
MOV AX, ARRAY[100]	12
ADD AX, 128	4
MOV CX, 4	4
MUL CX	118
MOV ARRAY[100], AX	13
AGAIN: MOV AX, ARRAY[200]	12
SUB AX, 256	4
MOV ARRAY[200], AX	13
MOV CX, AX	2
MOV AX, ARRAY[100]	12
SUB CX, AX	3
JCXZ AGAIN	18

So, the weights average CPI is

$$\mathrm{CPI}_{\mathrm{original}} = \frac{12+4+4+118+13+12+4+13+2+12+3+18}{12} = \frac{215}{12} \approx 17.92$$

2. With the given operation mode of ALU, the total instruction count of the original code could be reduced by using the following code:

```
        MOV     AX, ARRAY[100]
        ADD     AX, 128
        MOV     CX, 4
        MUL     CX
        MOV     ARRAY[100], AX
AGAIN:  SUB     ARRAY[200], 256
        MOV     CX, ARRAY[200]
        SUB     CX, AX
        JCXZ    AGAIN
```

We still count each instruction once for calculating the clock cycles, and the number of total instructions for the new code is 9. Details of each instruction and its corresponding clock cycle are listed on the following table:

Instruction	**Clock Cycles**
MOV AX, ARRAY[100]	12
ADD AX, 128	4
MOV CX, 4	4
MUL CX	118
MOV ARRAY[100], AX	13
AGAIN: SUB ARRAY[200], 256	25
MOV CX, ARRAY[200]	12
SUB CX, AX	3
JCXZ AGAIN	18

So, the weights average CPI is

$$\mathrm{CPI}_{\mathrm{new}} = \frac{12+4+4+118+13+24+12+3+18}{9} = \frac{209}{9} \approx 23.22$$

Assume the clock cycle time is t, and it does not change during the execution of the original and the new code. The speedup of the new code is

$$\begin{aligned}\mathrm{Speedup} &= \frac{\mathrm{ExecutionTime}_{\mathrm{original}}}{\mathrm{ExecutionTime}_{\mathrm{new}}} \\ &= \frac{\mathrm{ClockCycles}_{\mathrm{original}} \times \mathrm{ClockCycleTime}_{\mathrm{original}}}{\mathrm{ClockCycles}_{\mathrm{new}} \times \mathrm{ClockCycleTime}_{\mathrm{new}}} \\ &= \frac{215t}{209t} \approx 1.03\end{aligned}$$

Therefore, the new code improves the performance of the original one by 1.03x in execution time.