1. Compute the CPI for the following program and machine:
   - Program: 10% floating-point operations, 20% memory access instructions, 40% branch/jump instructions, and the rest are ALU operations.
   - Machine: cycles required for each of the following operations:
     - floating-point operations: 11 cycles
     - memory access instructions: 50 cycles*
     - branch/jump instructions: 5 cycles*
     - ALU operations: 2 cycles

$$\begin{aligned} \text{CPI} &= 0.10 \times 11 + 0.20 \times 50 + 0.40 \times 5 + (1 - 0.10 - 0.20 - 0.40) \times 2 \\ &= \boxed{13.7} \end{aligned}$$

2. Assume that we are running the *same application (not necessarily the same executable)* with the *same inputs* on two different systems. **What is the *speedup* of System B relative to System A?**
   - System A:
     - Instruction count: 3 million
     - Cycles per instruction: 4.7
     - Seconds per cycle: 1ns
   - System B:
     - Instruction count: 4 million
     - Cycles per instruction: 2.3
     - Seconds per cycle: 1ns

System A is the "old" system, so it goes on top of the speedup equation.

$$\text{Speedup} = \frac{\text{Latency}_{\text{old}}}{\text{Latency}_{\text{new}}} = \frac{3\cancel{\text{million}} \times 4.7 \times 1\cancel{ns}}{4\cancel{\text{million}} \times 2.3 \times 1\cancel{ns}} = \boxed{1.5326}$$

3. Assume that we are running the *same program* with the *same inputs* on two different systems. **What is the *speedup* of System B relative to System A?**

   - System A:
     - Instructions per cycle: 0.4
     - Clock speed: 3.7 GHz
   - System B:
     - Instructions per cycle: 0.3
     - Clock speed: 4.0 GHz

Same program means same IC

$$\text{Speedup} = \frac{\text{Latency}_{\text{old}}}{\text{Latency}_{\text{new}}} = \frac{\cancel{IC} \times \frac{1}{0.4} \times \frac{1}{3.7GHz}}{\cancel{IC} \times \frac{1}{0.3} \times \frac{1}{4.0GHz}} = \boxed{0.8108}$$

4. You have a processor that runs at 4.9 GHz with a CPI of 1.4.

   You can either spend $10,000 to hire a CS@Mines graduate for two weeks to optimize your algorithm so that it requires 37% less instructions to execute as before (assume same CPI).

   Or, you can spend $1500 on a new CPU that runs at 5.3 GHz (with the same CPI).

   Which option gives you the biggest speedup per dollar spent?

Speedup to dollar spent ratio for Mines grad:

$$\text{Speedup} = \frac{\text{Latency}_{\text{old}}}{\text{Latency}_{\text{new}}} = \frac{\cancel{IC} \times \cancel{1.4} \times \cancel{\frac{1}{4.9GHz}}}{(1 - 0.37)\cancel{IC} \times \cancel{1.4} \times \cancel{\frac{1}{4.9GHz}}} = 1.5873$$

$$\text{Speedup to dollar spent ratio} = \frac{1.5873}{\$10,000} = 0.00015873$$

Speedup of new CPU

$$\text{Speedup} = \frac{\text{Latency}_{\text{old}}}{\text{Latency}_{\text{new}}} = \frac{\cancel{IC} \times \cancel{1.4} \times \frac{1}{4.9GHz}}{\cancel{IC} \times \cancel{1.4} \times \frac{1}{5.3GHz}} = 1.0816$$

$$\text{Speedup to dollar spent ratio} = \frac{1.0816}{\$1,500} = 0.0007211$$

Getting a new CPU is probably the better investment unless you *really* need to get every bit of possible performance.