$$\text{CPU Time} = \text{CPU Clock Cycles} \times \text{Clock Cycle Time}$$

$$\text{CPU Time} = \frac{\text{CPU Clock Cycles}}{\text{Clock Rate}}$$

$$\text{Clock cycle Time} = \frac{1}{\text{Clock Rate}}$$

Problem: Our favorite program runs in 10 seconds on computer A, which has a 2GHz clock. We are trying to help a computer designer build a computer, B, which will run this program in 6 seconds. The designer has determined that a substantial increase in the clock rate is possible, but this increase will affect the rest of the CPU design, causing computer B to require 1.2 times as many clock cycles as computer A for this program. What clock rate should we tell the designer to target?

computer A

$\text{CPU Time}_A = 10\ S$

$\text{Clock Rate}_A = 2\ \text{GHZ}$

$= 2 \times 10^9\ \text{HZ}$

Computer B

$\text{CPU Time}_B = 6\ S$

$\text{Clock-cycle}_B = 1.2 \times \text{clock-cycles}_A$

$\text{clock Rate}_B = ?$

$\boxed{A}$

$\text{clock-cycle}_A = \text{CPU TIME}_A * \text{clock Rate}_A$

$= 10 * 2 * 10^9$

$= 20 * 10^9\ \text{HZ}$

$\text{Clock-cycle}_B = 1.2 * 20 * 10^9$

$= 24 \times 10^9$

$$\text{Clock-Rate}_B = \frac{\text{CPU Clock cycles}}{\text{CPU Time}}$$

$$= \frac{24 \times 10^9}{6}$$

$$= 4 \times 10^9 \text{ HZ.}$$

Instruction Count and CPI

(IC) Instruction Count: The number of instructions executed by the program.

(CPI) CPI (Clock cycles per instruction): Average number of clock cycles per instruction for a program.

$$\text{CPU Clock-cycles} = \text{IC} \times \text{CPI}.$$

$$\boxed{\begin{aligned}\textbf{CPU Time} &= \textbf{Instruction Count X CPI X Clock Cycle Time}\\ &= \frac{\textbf{Instruction Count X CPI}}{\textbf{Clock Rate}}\end{aligned}}$$

$$\frac{\text{performance}_A}{\text{performance}_B} = \frac{\text{CPU Time}_B}{\text{CPU Time}_A} \qquad IC = I$$

Problem: Suppose we have two implementations of the same instruction set architecture. Computer A has a clock cycle time of 250ps and a CPI of 2.0 for some program, and computer B has a clock cycle time of 500ps and a CPI of 1.2 for the same program. Which computer is faster for this program and by how much?

A	B
clock-cycle Time$_A$ = 250 ps	clock-cycle Time$_B$ = 500 ps
$CPI_A = 2.0$	$CPI_B = 1.2$
$IC_A = I$	$IC_B = I$

$$\text{CPU Time}_B = I * 1.2 * 500 \text{ ps} \quad \text{--- (1)}$$

$$\text{CPU Time}_A = I * 2.0 * 250 \text{ ps} \quad \text{--- (2)}$$

$$\frac{\text{CPU Time}_B}{\text{CPU Time}_A} = \frac{\cancel{I} * 1.2 * 500 \text{ ps}}{\cancel{I} * 2.0 * 250 \text{ ps}}$$

$$\frac{\text{performance}_A}{\text{performance}_B} = 1.2$$

$$\boxed{\text{performance}_A = 1.2 \times \text{performance}_B}$$

① $a = 2$
② $a = a - 3$
③ $b = a * 5$

CPI in More Detail

If different instruction class take different number of cycles

Instruction count

* $$\boxed{\text{CPU clock cycles} = \sum_{i=1}^{n} CPI_i \times C_i = CPI_1 C_1 + CPI_2 C_2 + \cdots + CPI_n C_n}$$

* Weighted Average CPI

$$\boxed{CPI = \frac{\text{CPU clock cycles}}{\text{Instruction count}}}$$

Problem: A compiler designer is trying to decide between two code sequences for a computer. For a particular high-level language, the compiler writer is considering two code sequences that requires the following instruction counts. *Which code sequence executes the most instructions? Which will be faster? What is the CPI for each sequence?

Class	A	B	C	
CPI	1	2	3	
IC in code sequence 1	2	1	2	$2+1+2=5$
IC in code sequence 2	4	1	1	$4+1+1=6$

Code sequence 2 executes most instruction

$$\text{CPU clock-cycles}_1 = CPI_A\, C_A + CPI_B\, C_B + CPI_C\, C_C$$
$$= 1 \cdot 2 + 2 \cdot 1 + 3 \cdot 2$$
$$= 2 + 2 + 6$$
$$= 10$$

$$\text{CPU clock-cycles}_2 = \cancel{CPI_B\, C_B +}$$
$$= 4 \cdot 1 + 1 \cdot 2 + 1 \cdot 3$$
$$= 9$$

Code- sequence 2 is fasten.

$$CPI_1 = \frac{\text{CPU clock cycle}_1}{\text{Instruction Count } 1}$$
$$= \frac{10}{5} = 2$$

$$CPI_2 = \frac{9}{6} = 1.5.$$