Proof of Study 1

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Problem 1

The following table shows two different processors with identical clock frequencies (clock rates) and very different relative performance scores. In fact, one processor has nearly twice the performance over the other.

Processor Name	**Frequency**	**Relative Performance**
Intel Core i9-9900K *(Faster)*	3.60GHz	2,898
Intel Core i5-680 *(Slower)*	3.60GHz	1,550

What is causing this dramatic difference between the performance? According to the equations of performance and execution time, frequency is not the only factor. Assuming that the numbers of instructions are the same for both processors when running the testing program, the CPI (cycles per instruction) makes all the difference.

$$Execution\ time = \frac{Instructions\ [I] \times Cycles\ per\ instruction\ [CPI]}{Frequency}$$

$$Performance = \frac{1}{Execution\ time}$$

Therefore,

$$Performance = \frac{Frequency}{I \times CPI}$$

According to the table, assuming that the base processor (which the processors' performance scores are relative to) has a performance of 1s^{-1}, for each processor,

$$2,898s^{-1} = \frac{3.6\times10^{9}Hz}{I \times CPI_{Faster}}$$

$$1,550s^{-1} = \frac{3.6\times10^{9}Hz}{I \times CPI_{Slower}}$$

Therefore, assuming the numbers of instructions are the same for both processors,

$$\frac{CPI_{Faster}}{CPI_{Slower}} = \frac{3.6\times10^{9}Hz \div (2,898s^{-1} \times I)}{3.6\times10^{9}Hz \div (1,550s^{-1} \times I)} = \frac{1,550s^{-1}}{2,898s^{-1}} \approx 0.535$$

Meaning that **the faster processor *(Intel Core i9-9900K)* has a CPI that is about 53.5% of the CPI that the slower processor *(Intel Core i5-680)* has**.

Problem 2

The following table provides two processors of the same family that have different frequencies.

Processor Name	Frequency	Relative Performance
Intel Core i9-9900K *(Faster)*	3.60GHz	2,898
Intel Core i9-7960X *(Slower)*	2.80GHz	2,337

What is the difference between their CPIs? From the previous problem:

$$Performance = \frac{Frequency}{I \times CPI}$$

Therefore, for each of the processors (with the assumption that the base processor has a performance score of 1s^{-1}),

$$2,898s^{-1} = \frac{3.6\times10^{9}Hz}{I \times CPI_{Faster}}$$

$$2,337s^{-1} = \frac{2.8\times10^{9}Hz}{I \times CPI_{Slower}}$$

And assuming that they have the same number of instructions,

$$\frac{CPI_{Faster}}{CPI_{Slower}} = \frac{3.6\times10^{9}Hz \div (2,898s^{-1} \times I)}{2.8\times10^{9}Hz \div (2,337s^{-1} \times I)} = \frac{3.6\times10^{9}Hz \times 2,337s^{-1}}{2.8\times10^{9}Hz \times 2,898s^{-1}} \approx 1.04$$

Meaning that **the faster processor *(Intel Core i9-9900K)* has a CPI that is about 104% of the CPI that the slower processor *(Intel Core i5-680)* has**. It may sound surprising that the slower processor has a lower CPI, but it makes sense if we take the ratios into account. The frequency of the faster processor is about 129% *(3.6GHz / 2.8GHz)* of the slower processor, but the faster processor's performance score is only 124% *(2,898 / 2,337)* of the slower. The slower processor performs relatively better than expected, therefore, its CPI must make up for it and be less than the faster processor's CPI (assuming the same number of instructions, of course).

Problem 3

According to the equation of yield,

$$Yield \approx \frac{1}{[1 + (Defects\ per\ area \times \frac{Die\ area}{2})]^2}$$

The number of defects per area is not the only factor of yield. **A smaller die area can compensate for the increase in defects per area and even increase the yield**.

Problem 4

- The program responds with 469,193 to my student number 1,172,983.
- The program responds to 2,932,458 with my student number 1,172,983.
- The program always responds to the input with ***int(input / 2.5)*** (if the input is positive, or 0 if it is negative).