CA homework1

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1.5

a.

$$
\begin{aligned}
\mathrm{P}_1 &: \frac{3\times 10^9\mathrm{Hz}}{1.5\ \text{cycles/ins}} = 2\times 10^9\ \text{ins/sec} \\
\mathrm{P}_2 &: \frac{2.5\times 10^9\mathrm{Hz}}{1.0\ \text{cycles/ins}} = 2.5\times 10^9\ \text{ins/sec} \\
\mathrm{P}_3 &: \frac{4.0\times 10^9\mathrm{Hz}}{2.2\ \text{cycles/ins}} \approx 1.818\times 10^9\ \text{ins/sec}
\end{aligned}
$$

hence, P_2 is the processor with the highest performance.

b.

$$
\begin{aligned}
\mathrm{P}_1 &: 3\mathrm{GHz} \to 10(\mathrm{sec})\times 3\times 10^9 = 3\times 10^{10}(\mathrm{cycles}) \\
&\quad \text{from a.} \to 10(\mathrm{sec})\times 2\times 10^9 = 2\times 10^{10}(\mathrm{ins}) \\
\mathrm{P}_2 &: 2.5\mathrm{GHz} \to 10(\mathrm{sec})\times 2.5\times 10^9 = 2.5\times 10^{10}(\mathrm{cycles}) \\
&\quad \text{from a.} \to 10(\mathrm{sec})\times 2.5\times 10^9 = 2.5\times 10^{10}(\mathrm{ins}) \\
\mathrm{P}_3 &: 4.0\mathrm{GHz} \to 10(\mathrm{sec})\times 4.0\times 10^9 = 4\times 10^{10}(\mathrm{cycles}) \\
&\quad \text{from a.} \to 10(\mathrm{sec})\times 1.818\times 10^9 = 1.818\times 10^{10}(\mathrm{ins})
\end{aligned}
$$

c.

$$\text{CPU Time} = \frac{\text{Instructions}}{\text{Program}} \times \frac{\text{Clock Cycles}}{\text{Instructions}} \times \frac{\text{Seconds}}{\text{Clock Cycles}}$$

CPU Time 30% $\downarrow$, CPI 20% $\uparrow$ Instruction Count stays unchanged

$$\Rightarrow \frac{\text{Seconds}}{\text{Clock Cycles}} : \frac{0.7}{1.2} \times 100\%$$

$$\Rightarrow \frac{\text{Clock Cycle}}{\text{Seconds}} : \frac{1.2}{0.7} \times 100\% \approx 171.43\%$$

$\Rightarrow$ Clock Rate 71.43% $\uparrow$

$$\Rightarrow \text{new Clock Rate} = \frac{1.2}{0.7} \times \text{old Clock Rate}$$

Therefore, the clock rate of each processor is as follows.

$$P_1 : 3(\text{GHz}) \times \frac{1.2}{0.7} \approx 5.14(\text{GHz})$$

$$P_2 : 2.5(\text{GHz}) \times \frac{1.2}{0.7} \approx 4.29(\text{GHz})$$

$$P_3 : 4(\text{GHz}) \times \frac{1.2}{0.7} \approx 6.86(\text{GHz})$$

1.6

a.

$$\begin{aligned}
P_1 : \text{Clock Cycles} &= 10^6 \times (0.1 \times 1 + 0.2 \times 2 + 0.5 \times 3 + 0.2 \times 3) \\
&= 2.6 \times 10^6 (\text{cycles}) \\
\text{global CPI} \quad &= \frac{\text{Clock Cycles}}{\text{Instruction}} = \frac{2.6 \times 10^6}{10^6} = 2.6 \\
P_2 : \text{Clock Cycles} &= 10^6 \times (0.1 \times 2 + 0.2 \times 2 + 0.5 \times 2 + 0.2 \times 2) \\
&= 2 \times 10^6 (\text{cycles}) \\
\text{global CPI} \quad &= \frac{2 \times 10^6}{10^6} = 2
\end{aligned}$$

b.

$$
\begin{aligned}
\mathrm{P}_1 : \text{Clock Cycles} &= 10^6 \times (0.1 \times 1 + 0.2 \times 2 + 0.5 \times 3 + 0.2 \times 3) \\
&= 2.6 \times 10^6 (\text{cycles}) \\
\mathrm{P}_2 : \text{Clock Cycles} &= 10^6 \times (0.1 \times 2 + 0.2 \times 2 + 0.5 \times 2 + 0.2 \times 2) \\
&= 2 \times 10^6 (\text{cycles})
\end{aligned}
$$

$$
\begin{aligned}
\mathrm{P}_1 &: \frac{2.6 \times 10^6}{2.5 \times 10^9} = 0.00104(\text{sec}) \\
\mathrm{P}_2 &: \frac{2 \times 10^6}{3 \times 10^9} \approx 0.00067(\text{sec})
\end{aligned}
$$

$\Longrightarrow$ P_2 is faster.

1.7

a.

$$
\begin{aligned}
\text{The clock cycle of compiler A} &= \frac{1.1(\text{sec})}{10^{-9}(\text{sec})} = 1.1 \times 10^9 (\text{cycles}) \\
\text{average CPI of compiler A} &= \frac{\text{Clock Cycles}}{\text{Instructions}} = \frac{1.1 \times 10^9}{10^9} = 1.1 \\
\text{The clock cycle of compiler B} &= \frac{1.5(\text{sec})}{10^{-9}(\text{sec})} = 1.5 \times 10^9 (\text{cycles}) \\
\text{average CPI of compiler B} &= \frac{\text{Clock Cycles}}{\text{Instructions}} = \frac{1.5 \times 10^9}{1.2 \times 10^9} = 1.25
\end{aligned}
$$

b.

$$\begin{aligned}
&\because \text{the execution times are the same}\\
&\text{CPU Time} = \text{Clock Cycles} \times \text{Clock Cycle Time}\\
&\Rightarrow \text{Clock Cycle Time} = \frac{\text{CPU Time}}{\text{Clock Cycles}}\\
&\therefore \frac{\text{A's Clock Cycle Time}}{\text{B's Clock Cycle Time}} = \frac{1.5 \times 10^9}{1.1 \times 10^9} \approx 1.36
\end{aligned}$$

c.

$$\begin{aligned}
&\text{Clock Cycle Time is the same for all compilers}\\
&\text{Clock Cycles of compiler C} = 1.1 \times 6 \times 10^8 = 6.6 \times 10^8 (\text{cycles})\\
&\text{CPU Time (T)} = \text{Clock Cycles} \times \text{Clock Cycle Time}\\
&\frac{\mathrm{T}_A}{\mathrm{T}_C} = \frac{1.1 \times 10^9}{6.6 \times 10^8} \approx 1.67\\
&\frac{\mathrm{T}_B}{\mathrm{T}_C} = \frac{1.5 \times 10^9}{6.6 \times 10^8} \approx 2.27
\end{aligned}$$

1.11

1.11.1

$$\begin{aligned}
\text{CPI} &= \frac{\text{CPU Time/Clock Cycle Time}}{\text{Instructions}}\\
&= \frac{750/(0.333 \times 10^{-9})}{2.389 \times 10^{12}} \approx 0.94
\end{aligned}$$

1.11.2

$$\text{SPECratio} = \frac{\text{reference time}}{\text{execution time}} \Rightarrow \frac{9650}{750} \approx 12.87$$

1.11.3

$$\begin{aligned}
&\text{CPU Time} = \text{CPI} \times \text{Instructions} \times \text{Clock Cycle Time} \\
&\because \text{CPI and Clock Cycle Time keep unchanged} \\
&\therefore \text{Instructions: } 10\% \uparrow \Longrightarrow \text{ CPU Time: } 10\% \uparrow \\
&\text{increase by } 750 \times 10\% = 75(\text{sec})
\end{aligned}$$

1.11.4

$$\begin{aligned}
&\text{CPU Time} = \text{CPI} \times \text{Instructions} \times \text{Clock Cycle Time} \\
&\because \text{Clock Cycle Time keeps unchanged} \\
&\therefore \text{Instructions: } 10\% \uparrow \text{ and CPI: } 5\% \uparrow \\
&\Longrightarrow \text{ CPU Time: } 1.1 \times 1.05 = 1.155 \Rightarrow 15.5\% \uparrow \\
&\text{increase by } 750 \times 15.5\% = 116.25(\text{sec})
\end{aligned}$$

1.11.5

$$\begin{aligned}
&\text{SPECratio} = \frac{\text{reference time}}{\text{execution time}} \\
&\frac{\text{new execution time}}{\text{old execution time}} = \frac{1.155}{1} \Rightarrow \frac{\text{new SPECratio}}{\text{old SPECratio}} = \frac{1}{1.155} \approx 0.87 \\
&\Rightarrow \text{SPECratio: } 13\% \downarrow \\
&\text{new SPECratio } = \frac{9650}{750} \times \frac{1}{1.155} \approx 11.14
\end{aligned}$$

1.11.6

$$\begin{aligned}
\text{CPU Time} &= \frac{\text{CPI} \times \text{Instructions}}{\text{Clock Rate}} \\
\Rightarrow \text{CPI} &= \frac{\text{CPU Time} \times \text{Clock Rate}}{\text{Instructions}} = \frac{700(\text{sec}) \times 4 \times 10^9(\text{Hz})}{2.389 \times 10^{12} \times 0.85} \\
&\approx 1.38
\end{aligned}$$

1.11.7

$$\frac{\text{new CPI}}{\text{old CPI}} = \frac{1.38}{0.94} \approx 1.47$$
$$\frac{\text{new Clock Rate}}{\text{old Clcok Rate}} = \frac{4}{3} \approx 1.33$$

They are dissimilar because the number of instructions has been reduced.

1.11.8

$$\frac{\text{new CPU Time}}{\text{old CPU Time}} = \frac{700}{750} \approx 0.93$$

Hence, CPU time has been reduced by about 6.67%

1.11.9

$$\begin{aligned}\text{Instructions} &= \frac{\text{CPU Time} \times \text{Clock Rate}}{\text{CPI}} \\ &= \frac{960 \times 10^{-9} \times 0.9 \times 4 \times 10^{9}}{1.61} \\ &\approx 2146.58\end{aligned}$$

1.11.10

$$\frac{\text{new Clock Rate}}{\text{old Clock Rate}} = \frac{\text{old CPU Time}}{\text{new CPU Time}} = \frac{1}{0.9} \approx 1.11$$

$$\Rightarrow \text{new Clcok Rate} = 1.11 \times \text{old Clock Rate} = 3.33(\text{GHz})$$

1.11.11

$$\frac{\text{new Clock Rate}}{\text{old Clock Rate}} = \frac{\text{new CPI} \times \text{old CPU Time}}{\text{old CPI} \times \text{new CPU Time}} = \frac{0.85}{0.8} = 1.0625$$

$$\Rightarrow \text{new Clock Rate} = 1.0625 \times \text{old Clock Rate}$$

$$= 1.0625 \times 3 \approx 3.19(\text{GHz})$$

1.14

1.14.1

$$
\begin{aligned}
&\text{old Clock Cycles} = \sum \text{CPI} \times \text{Instructions} \\
&= 1 \times 50 \times 10^6 + 1 \times 110 \times 10^6 + 4 \times 80 \times 10^6 + 2 \times 16 \times 10^6 \\
&= 512 \times 10^6 \\
&\text{CPU Time} = \frac{\text{Clock Cycles}}{\text{Clock Rate}} \propto \text{Clock Cycles} \\
&\frac{\text{old CPU Time}}{\text{new CPU Time}} = \frac{\text{old Clock Cycles}}{\text{new Clock Cycles}} = 2 \\
&\Rightarrow \text{new Clock Cycles} = \frac{1}{2} \times \text{old Clcok Cycles} = 256 \times 10^6 \\
&\text{CPI}_{FP} \times 50 \times 10^6 + 462 \times 10^6 = 256 \times 10^6 \\
&\Rightarrow \text{CPI}_{FP} < 0 \text{ ,which is impossible}
\end{aligned}
$$

1.14.2

$$
\begin{aligned}
&\text{from 1.14.1} \\
&\Rightarrow \text{CPI}_{L/S} \times 80 \times 10^6 + 192 \times 10^6 = 256 \times 10^6 \\
&\Rightarrow \text{CPI}_{L/S} = \frac{256 - 192}{80} = 0.8
\end{aligned}
$$

1.14.3

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

$$\frac{\text{new CPU Time}}{\text{old CPU Time}} = \frac{\text{new Clock Cycles}}{\text{old Clock Cycles}}$$

$$= \frac{0.6 \times 1 \times (50 \times 10^6 + 110 \times 10^6) + 0.7 \times (4 \times 80 \times 10^6 + 2 \times 16 \times 10^6)}{512 \times 10^6}$$

$$= \frac{342.4 \times 10^6}{512 \times 10^6} = 0.66875 = 66.875\%$$

$$\Rightarrow \text{execution time } 33.125\% \downarrow$$

$$\text{old CPU Time} = \frac{\text{old Clock Cycles}}{\text{Clock Rate}} = \frac{512 \times 10^6(\text{cycles})}{2 \times 10^9(\text{Hz})} = 0.256(\text{sec})$$

$$\Rightarrow \text{new CPU Time} = 0.66875 \times 0.256 = 0.1712(\text{sec})$$

$$\Rightarrow \text{improve } 0.256 - 0.1712 = 0.0848(\text{sec})$$